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Dr. Helfried Oswald
Directeur de recherche
I.N.R.A. Station de sylviculture méditerranéenne
12, avenue A. Vivaldi
F-84000 Avignon
France

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INTENSIFICATION DE LA SYLVICULTURE DU PIN MARITIME DANS LES LANDES DE GASCOGNE : RESULTATS ET PERSPECTIVES DE RECHERCHES INTEGREES.

M. ARBEZ (1), P. BARADAT (1), J. GELPE (1), B. LEMOINE (1), JP. MAUGE (2).

(1) INRA STATION DE RECHERCHES FORESTIERES PIERROTON. 33610 CESTAS FRANCE.
(2) CPFA. CENTRE DE PRODUCTIVITE FORESTIERE D'AQUITAINE, RUE ESPRIT DES LOIS. 33000. BORDEAUX. FRANCE.

FDC: 238: 174.7 Pinus pinaster Ait.: 907: (44)

RESUME

La forêt française de Pin maritime (*Pinus pinaster Ait.*) couvre plus d'un million d'hectares dans les Landes de Gascogne. Cette forêt artificielle monospécifique est cultivée de manière intensive. Depuis 25 ans, sa productivité a doublé, passant de 4.7m³/ha/an en 1962 à 9.0m³/ha/an en 1987. Cette augmentation spectaculaire des rendements résulte surtout de l'intensification progressive de la sylviculture. La poursuite de l'intensification et l'utilisation des variétés améliorées permettront d'accroître encore les performances de la forêt landaise : la productivité pourrait atteindre 14m³ /ha/an et l'âge d'exploitibilité passer de 65 à 40 ans. Des recherches parallèles sur le fonctionnement de l'écosystème forestier landais sont cependant recommandées pour atteindre ces objectifs sans risques excessifs pour la santé des forêts et l'intégrité des ressources naturelles (fertilité des sols et disponibilités en eau). Cette problématique de recherche, propre aux forêts cultivées intensives, est rapidement présentée et discutée.

Mots clés : forêt cultivée, intensification, *Pinus pinaster Ait.* , variétés améliorées, écosystème forestier.

SUMMARY

The french forest of maritime pine (*Pinus pinaster Ait.*) covers more than one million hectares in the Landes of Gascony. This monospecific artificial forest is intensively cultivated. Since 25 years, its productivity was doubled, from 4,7m³/ha/year in 1962 to 9,0m³/ha/year in 1987. This spectacular yield increase mainly results from the progressive intensification of the sylviculture.

. Carrying out of this intensification and use of selected varieties allow to still increase the performances of the Landes forest : the productivity could reach 14m³/ha/year and the rotation age could pass from 65 to 40 years. Parallel researches about functionning of the Landes forest ecosystem are nevertheless recommanded to reach these objectives without excessive risks for health of forests and entirety of natural resources (sol fertility and water availability). Such a research problematic suited to intensive cultivated forests is quickely presented and discussed.

• Key words : *Pinus pinaster Ait.*, cultivated forest, intensification, selected varieties, forest écosystem.

INTRODUCTION

La forêt artificielle de Pin maritime des Landes de Gascogne couvre aujourd'hui près d'un million d'hectares, dont une part importante cultivée de façon intensive. C'est une création récente. Certes, *Pinus pinaster* est autochtone et ce massif a été majoritairement constitué à partir de la race locale, mais, depuis deux siècles, l'homme a doublé sa surface et considérablement élargi la gamme des milieux qui lui étaient originellement dévolus. Depuis 30 ans, la sylviculture traditionnelle, autrefois caractérisée par la régénération naturelle , le gemmage et les faibles densités finales, a cédé le pas à la culture intensive : drainage, labour et fertilisation, entretiens et éclaircies fréquentes. Comme en agriculture, les variétés améliorées font aujourd'hui leur apparition en forêt et ouvrent de nouvelles possibilités de progrés. Les gains de croissance, déjà obtenus et encore perfectibles sont spectaculaires. La forêt cultivée est source de richesse pour la région Aquitaine, elle nourrit à l'aval un appareil industriel puissant et diversifié : 30.000 emplois, 3,3 milliards de FF de valeur ajoutée chaque année, 800 000 tonnes de pate kraft, 1.400.000m³ de sciages et 300 000m³ de bois déroulé.

Cette intensification et l'augmentation de productivité qu'elle génère peuvent-elles se poursuivre encore longtemps sans risque pour la santé des forêts et la fertilité des sols? Quelles recherches doivent être engagées pour répondre à la question et assurer l'avenir?

I. LES FRUITS DU PROGRES TECHNIQUE

1.1. L'amélioration des propriétés physiques et chimiques des sols.

Les sols landais sont sableux et acides (pH 4 à 4.5), pauvres sur le plan minéral et disposant de réserves en eau très faibles. A l'inverse, ils sont faciles à travailler et se ressuient très vite lorsqu'ils sont drainés. L'effet combiné du labour et de la fertilisation phosphatée permet de doubler la production en volume dans des conditions rentables (GUINAUDEAU *et Al* 1963, MAUGE 1984). Cette constatation expérimentale est le premier moteur de l'intensification de la culture du Pin maritime.

Bien que son effet n'ait pas été chiffré séparément, le drainage a eu un effet très positif sur l'intensification de la sylviculture en lande humide. Il améliore l'accès aux parcelles en toute saison (régularité des opérations sylvicoles, débroussaillements notamment), et par conséquent, la prévention et la lutte contre les incendies.

Même en tenant compte du rajeunissement du Massif forestier pendant et après la dernière guerre, on considère que le drainage, la plus grande fréquence des entretiens et aussi la disparition progressive des dernières éclaircies provoquées par l'abandon du gemmage, ont joué un rôle majeur dans l'augmentation spectaculaire de productivité entre les 3 passages de l'Inventaire Forestier National :

4,7 m^3/ha/an en 1962
7,3 m^3/ha/an en 1977
9,0 m^3/ha/an en 1987.

Les conséquences favorables du labour et de la fertilisation n'ont commencé à se faire sentir sur la croissance des plus jeunes classes d'âge qu'à partir du troisième cycle de l'Inventaire (1987). Leur impact sur la productivité globale du Massif reste donc encore faible.

Le travail du sol, de plus en plus efficace avec l'augmentation progressive de la puissance des tracteurs forestiers, joue un rôle majeur dans l'accroissement des rendements et l'amélioration de la qualité de la production du Pin maritime. On est passé en 20 ans du simple passage de débroussailleur au labour à la charrue à soc à 35 cm de profondeur, et du labour en bande au labour en plein. Il en est résulté une amélioration spectaculaire de la croissance et de la rectitude des arbres (meilleur enracinement et meilleure résistance au vent). Des progrés de même importance ont été faits en matière de lit de semence pour le semis direct (MAUGE 1986).

Combinée au labour, la fertilisation phosphatée augmente la croissance de manière spectaculaire (GUINAUDEAU et *Al.* 1963, BONNEAU et *Al.* 1972, MAUGE 1984, GELPE et *Al.* 1986, CHAPERON 1985 et 1989).

Dans certaines conditions (landes humides riches notamment) la fertilisation phosphatée peut s'accompagner parfois de conséquences défavorables : accentuation des défauts de forme (courbure basale du tronc et diamètre des branches) et sensibilité à la Pyrale du tronc, ***Dioryctria Sylvestrella***. (ALAZARD 1981). Ces aléas pourraient sans doute être corrigés par la pratique de l'élagage et l'utilisation de variétés améliorées bien adaptées. Des études sont en cours, pour vérifier que l'élagage de branches vertes n'augmente pas l'attractivité vis à vis de Dioryctria, et le cas échéant y remédier.

Dans certains cas (Vieille dune : Forêt domaniale de Mimizan), on observe un effet limité dans le temps de la fertilisation phosphatée : après une quinzaine d'années, la vitesse de croissance des pins fertilisés rejoint celle des témoins. Des vérifications et des recherches complémentaires sont en cours pour tenter d'expliquer ce phénomène et si nécessaire y porter remède.

La fertilisation phosphatée accroit le pourcentage de bois juvénile et, ce faisant, réduit globalement l'infra-densité du bois (Otha et *Al* 1983).

Recommandée en appoint par certains auteurs (CHAPERON 1989), la fertilisation azotée reste encore trés discutée.

1.2. La conduite des peuplements

La rationalisation de la conduite des peuplements, grâce à un programme d'éclaircies (intensité et périodicité) bien adapté aux objectifs de production choisis, constitue une caractéristique essentielle du progrès sylvicole. La disponibilité de modèles de gestion, opérationnels dès aujourd'hui, permet au sylviculteur d'évaluer la potentialité de croissance du peuplement, de simuler les résultats de plusieurs modes de conduite et de choisir celui qui convient le mieux à ses objectifs (MAUGE 1975 et 1984, LEMOINE 1982). L'étendue du massif, son caractère monospécifique, et la connaissance de sa structuration en classes d'âge ont justifié l'élaboration d'un modèle de production opérationnel au niveau du massif forestier dans son ensemble (MAUGE 1981 et MAUGE et *Al.* 1987). C'est un outil de décision précieux pour les industriels, soucieux d'asseoir leur politique d'investissement sur des prévisions précises de la ressource à venir. Cet outil permet en effet de mesurer les conséquences de scénarios de récolte donnés sur l'ensemble de la production, ainsi que sur le volume des exploitations et des régénérations de peuplement.

1.3. L'amélioration génétique du matériel de reproduction.

Les dernières décennies ont vu la réalisation de progrès importants dans ce domaine.

L'exploitation de tests de provenances agés de plus de trente ans aujourd'hui (ILLY 1966) a permis de concentrer les efforts de sélection sur la race landaise, plus productive et mieux adaptée aux conditions locales (froid et hydromorphie des sols en hiver). Abordé durant la période 1960-73 par la sélection phénotypique de 550 arbres plus (génération Fo) en forêt landaise, le programme s'est ensuite poursuivi activement jusqu'à nos jours (BARADAT et MARPEAU 1988). Outre l'adaptation au milieu local, deux critères de sélection principaux ont été choisis : le rendement (production en volume à un âge donné) et la rectitude du tronc. Ce dernier caractère a des répercussions favorables évidentes sur le centrage du coeur et la réduction du bois de compression. L'existence d'une corrélation génétique défavorable entre vigueur et grosseur de branches amène par ailleurs à miser d'abord sur l'élagage artificiel pour améliorer la qualité de la production sans réduire le gain potentiel de rendement.

Le travail du sélectionneur s'appuie sur la génétique quantitative et la mise en oeuvre d'un schéma d'amélioration structuré. Bien qu'il privilégie à court et moyen termes la race

landaise pour les utilisations locales, ce schéma évalue et utilise l'ensemble de la variabilité génétique de l'espèce *Pinus pinaster*, il combine sélection récurrente intra-raciale et recombinaisons inter-raciales (races des Landes et de Corse), enfin il sépare clairement la gestion des populations d'amélioration ("la cuisine du sélectionneur") et les sorties variétales proposées aux sylviculteurs.

Trente ans après son début, ce programme débouche sur une importante population d'amélioration F2 (près près de 2 500 géniteurs landais F1 sélectionnés) et la production de plusieurs variétés commerciales F1 et F2. Les vergers à graines de semis installés produisent aujourd'hui une variété "polyvalente" F2 représentant 15% de gain génétique pour la production en volume et 30% pour la rectitude. Les premières semences améliorées ne sont disponibles en quantité commerciale que depuis quelques années et il faudra encore attendre plusieurs décennies pour mesurer leur véritable impact sur la production. Un Verger de semis F_2 de 60 hectares (Malente) va prochainement entrer en production commerciale et permettra de porter respectivement à 25% et 50% les gains génétiques sur le volume et la rectitude du fût.

1.4. Les caractéristiques du bois produit.

Le Pin maritime produit un bois coloré, de propriétés mécaniques satisfaisantes, lorsqu'elles ne sont pas dépréciées par des singularités (noeuds, bois de compression provoqué par la courbure du tronc, fibre torse, A.F.E.F. 1988). Ces propriétés mécaniques, notamment la résistance à la rupture, importantes pour les emplois travaillants, sont très influencées par la densité du bois. Celle-ci diminue globalement lorsque la proportion de bois juvénile augmente, notamment sous l'effet de la fertilisation phosphatée. Mais les emplois travaillants (utilisation du bois en structure) sont loin de représenter l'utilisation la plus valorisante du pin maritime, le parquet, le lambris ou le déroulage pour le contreplaqué résineux ont des exigences technologiques différentes pour lesquelles l'absence de noeuds est autrement plus importante que l'infra-densité globale. L'élagage artificiel précoce augmente d'ailleurs dans de telles proportions la valeur du produit final que l'on pourrait accepter des pertes de production en volume sans affecter la rentabilité financière de l'opération. L'élagage artificiel réduit également la durée de production du bois juvénile et augmente par conséquent l'infra-densité globale du bois.

La corrélation génétique entre vigueur et densité est faible ou nulle chez cette espèce, les gains de vigueur par sélection ne seront donc pas contrebalancés par d'éventuelles pertes de densité du bois produit (KELLER 1973).

Le bois de pin maritime est séché artificiellement aprés sciage pour lui conférer une stabilité dimensionnelle suffisante. Un effort d'investissement important est actuellement engagé par les scieries pour s'équiper de séchoirs performants (séchoirs à haute température notamment).

1.5. La commercialisation du bois.

Pour un accroissement physique voisin de 9 millions de m³, le massif récolte actuellement 6,1 millions de m³ (3,7 millions de m³ de bois d'oeuvre et 2,4 millions de m³ de bois d'industrie). La quasi-totalité du bois d'oeuvre est transformée sur place.

Des possibilités d'exportation existent néanmoins (notamment vers l'Espagne) pour autant que des structures de regroupement de l'offre soient en mesure de se mettre en place pour approvisionner le marché extérieur par voie routière ou maritime. Cette ouverture vers des marchés extérieurs est évidemment conditionnée par l'amélioration de la qualité (respect de normes dimensionnelles, absence de gros noeuds, sèchage) et la diminution des coûts unitaires de transport (CAILLEAU 1984).

2. UNE DEMARCHE DE RECHERCHE PLURIDISCIPLINAIRE A LA MESURE DES ENJEUX FUTURS.

Comme en agriculture, l'amélioration des rendements résulte du mariage réussi de l'intensification culturale et du progrès génétique. Il ne faut cependant pas oublier les concessions à faire et le prix à payer pour maintenir un fonctionnement équilibré de cet écosystème forestier très artificialisé : c'est indispensable pour sauvegarder la productivité et la santé du massif forestier sur le long terme. Dans cette analyse, les différentes composantes de l'évolution en cours et les recherches multidisciplinaires qui les sous-tendent seront successivement passées en revue : elles concernent l'augmentation de la productivité, l'amélioration de la qualité du bois et le maintien des équilibres entre la forêt et son milieu.

2.1. La poursuite de l'intensification sylvicole et l'augmentation continue des rendements.

Les impératifs de compétitivité internationale qui pèsent sur la production et la transformation du bois sont un aiguillon

permanent à poursuivre l'effort d'intensification de la sylviculture entrepris depuis 30 ans sur le massif forestier landais. Même si les gains de productivité déjà enregistrés sont spectaculaires, ils n'atteignent pas encore leurs limites biologiques. Sur le plan économique, malgré des investissements de départ plus importants, l'intensification réalisée jusqu'ici s'est avérée rentable pour la sylviculture. Les futurs progrès techniques ne passeront à la pratique que si leur rentabilité peut être démontrée. Qui pourrait se payer le luxe d'investir à perte ?

2.1.1. Le progrès variétal.

Il va se traduire de diverses manières : par de nouvelles variétés polyvalentes encore plus productives, par l'apparition de variétés plus spécialisées, par la généralisation des possibilités de reconnaissance et de contrôle variétal.

Aux premières variétés polyvalentes produites aujourd'hui à l'échelle commerciale et décrites au chapitre précédent, vont succéder à l'horizon 2000, celles résultant de la production des vergers à graines dits "d'équivalents clones" (ou polycross) en cours d'installation sur 180 ha. Les gains génétiques correspondants avoisineront 50 % sur la production en volume et pratiquement autant sur la rectitude du tronc (BARADAT 1986, ARBEZ 1986).

La conception des vergers polycross est très récente (BARADAT, 1987). Ils combinent plusieurs avantages : pour un même gain génétique le coût est inférieur et la recombinaison entre patrimoines génétiques des parents plus poussée que dans le cas des vergers de clones d'élite greffés. L'efficacité supérieure de la sélection sur descendances, la possibilité d'appliquer de fortes intensités de sélection sur les parents femelles et une intensité différentielle plus forte encore sur les parents mâles, permet, dès la seconde génération de sélection, d'atteindre des gains génétiques très supérieurs à ceux obtenus en vergers à graines de semis.

Aux variétés polyvalentes produites en vergers à graines polycross, s'ajouteront d'ici moins de 5 ans des variétés spécialisées ou "à la carte" résultant du mélange de croisements contrôlés de performances préalablement connues. Ces objectifs spécialisés pourront concerner suivant les cas l'adaptation à des conditions de milieu particulières (sécheresse ou hydromorphie : dune, lande sèche ou lande humide, froid : zone péri-landaise ou forêt d'Orléans), une qualité du bois très supérieure à celle des variétés polyvalentes (rectitude et branchaison, propriétés intrinsèques de la matière ligneuse) obtenue au prix d'un gain plus limité sur la croissance, ou une résistance marquée par rapport à certains insectes (*Dioryctria sylvestrella* ou Pyrale du tronc notamment).

Des variétés hybrides feront également leur apparition à brève échéance, à partir de croisements contrôlés entre géniteurs sélectionnés de races landaise et corse. Cette innovation, rendue possible par l'amélioration préalable de la race corse vis-à-vis de la résistance au froid et à *Dioryctria*, permettra d'atteindre des objectifs de qualité (rectitude et branchaison) inaccessibles par sélection intra-landaise.

Même si la différence de prix entre variétés améliorées et variété "sauvage" affecte peu l'investissement total à l'hectare de reboisement, ce surcoût suppose en contrepartie l'existence de tests variétaux permettant à des laboratoires spécialisés de reconnaître sans ambiguïté les variétés sélectionnées entre elles et de les distinguer des variétés sauvages. Chez le Pin maritime, des tests variétaux utilisant les différences de profil terpénique permettent déjà de reconnaître "en routine" les différentes races géographiques . Ceci permet de rendre effective l'interdiction d'utiliser des semences de Pin maritime d'origine ibérique pour le reboisement dans les Landes de Gascogne. Les recherches en cours permettront d'aller au-delà puisque l'incorporation aux variétés améliorées d'infimes quantités de "variétés marqueuses" permettra de les reconnaître rigoureusement à l'analyse, et ce dès le stade graine si les marqueurs utilisés sont de type isozymes ou protéines totales. Cette innovation dans le domaine des semences forestières permettra de protéger à la fois l'utilisateur et l'obtenteur des préjudices causés par d'éventuels fraudeurs.

2.1.2. La création et la conduite des peuplements.

Le semis direct représente encore près de 85 % des surfaces de reboisement. Le grand gibier (chevreuil, cerf) et de nombreuses adversités sanitaires (rouille courbeuse, hylobe, *Rhyacionia buoliana*...) limitent encore le développement des plantations. Cependant, le progrès des techniques des plantations et le coût des semences sélectionnées joueront en faveur d'un accroissement progressif des surfaces plantées.

Cette mutation technique est d'ailleurs la plus efficace pour rapprocher la demande de semences pour le reboisement (près de 40 tonnes par an aujourd'hui) et la capacité de production des vergers à graines (une tonne de semences améliorées en 1990). Les variétés spécialisées produites par croisements contrôlés contribueront partiellement à résorber ce déficit, en attendant l'entrée en production des vergers polycross à l'horizon 2000.

Une alternative défendue par certains auteurs consiste à poursuivre l'amélioration des techniques de semis (qualité du lit

de semence, précision des semoirs). Déjà les progrés accomplis sont importants : 15 à 20 kgs de graines utilisés à l'hectare en 1950, 2 à 4 kgs actuellement. Même si les surfaces annuelles dévolues à la plantation augmentent progressivement, il restera de nombreux cas justiciables du semis direct pour valoriser ces nouveaux progrés.

En conjuguant variétés améliorées et sylviculture intensive, on peut imaginer faire progresser la productivité moyenne en volume de 9 à 14 m³/ha/an, ou raccourcir l'âge d'exploitabilité de 65 à 40 ans en moyenne. Les répercussions sur la rentabilité financière des reboisements, l'évolution technique des scieries et les cadences annuelles de reboisement seraient considérables, avec un coup de fouet spectaculaire sur l'économie du massif forestier. Une progression de cette ampleur ferait notamment passer les surfaces à régénérer annuellement de 12.000 à près de 20.000 ha. L'utilisation raisonnée des débroussaillants chimiques (Velpar, Round up) offre de nouveaux avantages : il n'y a pas de tassement du sol par le tracteur ni de blessure de racines préjudiciable à la croissance et à la santé des arbres : l'eau et l'engrais ne profitent qu'au seul Pin maritime. La modicité des quantités utilisées sur la durée d'une révolution limite beaucoup l'éventualité de conséquences défavorables sur l'environnement. La disparition de la callune du fait des phytocides poserait cependant problème dans les zones où subsite l'apiculture. Bien que l'avantage du sous-solage profond (1,20m) semble discutable sur la croissance et que son coût soit encore prohibitif, les expérimentations dans ce sens doivent être poursuivies. On peut notamment en attendre une amélioration de la stabilité et par conséquent de la rectitude du tronc.

L'étude approfondie des besoins hydriques et minéraux du Pin maritime en fonction de l'âge et de la variété permettra de rationaliser la fertilisation, les entretiens et les éclaircies suivant les besoins de l'arbre et du peuplement et les objectifs de production. La connaissance des besoins hydriques respectifs du Pin maritime et de la végétation adventice, et du calendrier d'utilisation correspondant, permettrait de fixer de manière optimale les opérations de débroussaillement et d'en chiffrer l'impact sur la croissance du peuplement de Pin maritime. La caractérisation des lois de croissance et des exigences trophiques des variétés améliorées, comparées à celles des variétés sauvages, donnera au sylviculteur les moyens de tirer le meilleur parti possible des variétés améliorées aujourd'hui disponibles (BIROT 1986)..

2.2. L'amélioration de la qualité.

Pour des emplois travaillants, le bois de Pin maritime offre une résistance mécanique satisfaisante (NEPVEU et BLACHON 1989).Cette qualité mise en évidence sur des éprouvettes de bois sans défaut est défavorablement affectée par la mauvaise rectitude du tronc et la grosseur des branches. Ces défauts de l'arbre sont à l'origine des singularités du bois : coeur excentré dans la grume et inégalité des largeurs de cerne entre les expositions Est et Ouest, présence de bois de compression aux propriétés défavorables du coté Est (résistance mécanique plus faible, rendement papetier inférieur, fibres plus courtes), gros noeuds affaiblissant la résistance mécanique des pièces travaillantes ou handicapant beaucoup le déroulage et les utilisations nobles . Ces singularités du bois semblent d'ailleurs s'aggraver lorsque la fertilisation augmente exagérément la croissance, en stations riches et hydromorphes notamment : la sensibilité à Dioryctria s'accroit (ALAZARD 1981), et indépendamment, des poches de résine dont la formation est encore mal élucidée peuvent apparaître.

Plusieurs voies sont néanmoins possibles pour continuer à augmenter la productivité tout en améliorant la qualité du bois :

Les variétés améliorées polyvalentes aujourd'hui disponibles apportent un gain de rectitude de 20% par rapport au standard, celles résultant de l'entrée en production des vergers polycross augmentent ce gain jusqu'à 40%. Mais il est clair que l'utilisation de variétés spécialisées landaises ou hybrides, obtenues en reproduisant en masse les croisements contrôlés déjà testés pour un compromis optimal entre rectitude du tronc - finesse des branches et rapidité de croissance, permettront de dépasser très largement ces limites actuelles. La propagation en masse de mélanges de familles résistantes à Dioryctria pour des utilisations en situations exposées (stations très fertiles notamment) offrirait un avantage de même nature. Pour autant que soient maîtrisées par ailleurs les adversités résultant surtout de la présence de trop nombreux chevreuils (mise au point et utilisation de répulsifs appropriés) ou de la rouille courbeuse (existence de traitements chimiques efficaces en stations exposées), l'emploi des variétés améliorées permet d'obtenir plus vite des produits plus homogènes et de meilleure qualité.

L'étude de la mécanique de l'arbre sur pied, expliquant ses réactions au vent et sous l'action de son propre poids, améliorera notre compréhension des relations entre la sylviculture et les propriétés du bois produit : effet du

synchronisme de croissance de la partie aérienne et des racines sur le maintien d'une bonne verticalité, effet de l'importance de la masse foliaire et de sa répartition (polycyclisme) sur la sensibilité au vent de la partie aérienne, effet de la géométrie des espacements entre arbres sur l'équilibre des cimes et le taux de bois de compression dans le tronc ..ect.

De manière plus directe, l'élagage permet d'éviter la formation des noeuds, encore faut-il le faire sur de très jeunes arbres pour maximiser le volume de bois sans noeud. Mais des contradictions surgissent alors entre le raisonnement économique qui limiterait l'élagage aux seuls arbres d'avenir pour diminuer les dépenses, et la difficulté , voir l'impossibilité, d'identifier ces arbres avant la première éclaircie. Il faut également vérifier que la perte de croissance des arbres élagués par rapport aux non élagués voisins ne les pénalisent pas trop, identifier avec précision les mois de l'année où l'élagage est praticable sans préjudice durable pour l'arbre, et vérifier encore que l'élagage n'augmente pas la sensibilité à *Dyoryctria* ou trouver des méthodes permettant de prévenir cet alèa.

La généralisation de la pratique du séchage et son perfectionnement devraient considérablement améliorer par ailleurs la stabilité dimensionnelle des sciages et des produits transformés.

2.3. L'approche économique des problèmes.

C'est encore le point faible de la filière bois landaise et les besoins sont énormes, tant au niveau macro-économique que micro-économique.

Au niveau macro-économique de la production, quelques domaines sont actuellement étudiés (RAUSCENT 1982, CAILLEAU 1984): celui de la commercialisation (types et volumes de produits vendables à l'extérieur du massif, rôle des taxes et des distances de transport) et celui de la fiscalité (conséquences des impôts et des taxes sur l'économie de la production dans la perspective du Marché Unique Européen de 1993). Mais d'autres études manquent encore, notamment celle de l'économie de la filière bois landaise dans son ensemble :

- évaluation des flux en volume depuis l'exploitation du bois jusqu'à la commercialisation des produits de 2e transformation.
- chiffres d'affaire et valeurs ajoutées locales des différents secteurs de production et de transformation.
- évolution des emplois locaux.

De telles études sont nécessaires aux aménagistes régionaux pour mesurer les conséquences à moyen terme de leurs décisions : quelles importances respectives accorder à la filière bois et à la filière maïs en Aquitaine, à partir de l'impact de ces deux types d'activité sur l'économie et l'environnement régional? A ce niveau, les travaux de modélisation de la ressource forestière en fonction des différents scénarios possibles et l'étude de leurs répercussions sur les politiques d'investissement industriels sont particulièrement utiles.

Depuis les premières études de BERGMANN (1974), l'approche micro-économique se généralise dans la vie courante des sylviculteurs (rentabilité de la fertilisation et de l'élagage, rationalisation des éclaircies), la vulgarisation des méthodes de simulation et les possibilités de la micro-informatique y sont pour beaucoup (MAUGE 1984). Introduite depuis plus longtemps dans l'industrie, l'économie demeure l'outil de décision privilégié pour la modernisation des techniques (séchage, sciage...).

Mais la micro-économie reste encore très largement absente de nombreux domaines, le choix de l'importance relative des différents critères de sélection en est un. Le compromis choisi par le sélectionneur entre l'amélioration de la productivité en volume d'une variété forestière et celle de ses caractéristiques de qualité les plus importantes (rectitude du tronc, branchaison, densité du bois...) suit encore une démarche empirique. L'impact économique des différentes pondérations possibles entre caractères n'a que très exceptionnellement été étudié (CHOLLET et ROMAN-AMAT 1986).

2.4. La sauvegarde des équilibres écologiques

2.4.1. Adaptation et resistance des variétés vis à vis des adversités physiques et sanitaires.

La création de variétés adaptées s'appuie sur la réalisation de tests de provenances et de descendances multistationnels à moyen terme (périodicité longue des accidents climatiques : sécheresse ou froid). Chez le Pin maritime, les plus anciens datent maintenant de 60 ans et démontrent la meilleure adaptation au milieu local de la race landaise. Cette race sert donc de base et de fond génétique commun aux variétés créées ou en cours de création. L'élaboration de tests prècoces complètera cette approche traditionnelle et améliorera considérablement l'efficacité du selectionneur forestier (NGUYEN 1986).

Des variétés specialisées en vue d'une meilleure résistance à certains insectes (Dioryctria en zone landaise, Matsucoccus en zone méditérranéenne) peuvent être obtenues par sélection.

Parallèlement, l'étendue de la base génétique initiale, l'hétérozygotie et le niveau de variabilité interne des types de variétés utilisés (variétés synthétiques ou polycross) représentent la meilleure garantie de resistance vis à vis des adversités imprévisibles à venir . La conservation de l'essentiel de la variabilité intra-spécifique dans les plantations comparatives (provenances, descendances, clones) permettrait en cas de nécessité d'infléchir très rapidement les sorties variétales sur de nouveaux objectifs (modification majeure de l'environnement : CO_2, température, ou évolution des impératifs de la production industrielle).

2.4.2. Fonctionnement équilibré de l'écosystème forestier landais.

Les relations sol-plante-atmosphère caractéristiques de l'écosystème forestier landais, sont en cours d'étude. Ces observations permettent de chiffrer les exigences hydriques et minérales de l'écosystème Pin maritime actuel (race sauvage et sylviculture semi-intensive, LEMOINE et *Al* 1986 et 1988, MOUSSA 1989). Des observations semblables dans les expérimentations mettant en jeu les futures variétés améliorées ou les procédures sylvicoles les plus intensives permettront de prévoir et de modéliser leurs effets à long terme sur l'environnement. Par exemple l'inadéquation entre potentiel de croissance et exigences des variétés d'une part, ressources en eau et en éléments minéraux du sol d'autre part, pourrait entrainer l'appauvrissement excessif du sol ou le dépérissement de la forêt. Sans en arriver là, les bilans d'éléments minéraux au niveau du peuplement et l'étude des mécanismes de la nutrition minérale (SAUR 1989 et 1990) permettront de rationnaliser la fertilisation forestière, c'est à dire d'apporter quand il le faut les éléments qu'il faut aux quantités optimales. De la même manière, la pratique des bilans hydriques mensuels et saisonniers devrait permettre de mieux caler les réseaux de drainage et de rationnaliser la pratique du débroussaillage et des éclaircies.

Grâce à un réseau d'observateurs au sol, le massif forestier fait l'objet d'une surveillance permanente de la part du Service de la Santé des Forêts (Service National rattaché à la Sous-Direction des Forêts). Le niveau des populations de la processionnaire du Pin (*Thaumeatopea pithyocampa*) reste habituellement dans des limites acceptables grâce aux campagnes systématiques de pulvérisation de substances insecticides

sélectives (Toxine du *Bacillus Thuringiensis* et *Diflubenzuron*) 20000 ha ont ainsi été traités en 1989, plus de 100000 ha pourraient l'être en 1990 pour tenir compte du niveau très élevé de population cette année et des dommages très importants déjà enregistrés. Ce réseau d'observateurs suit également les éventuelles proliférations de scolytes et lance les avertissements de traitement. Le traitement insecticide généralisé des piles de bois au bord des routes forestières a permis d'éviter la prolifération catastrophique des Ips après que les froids de Janvier 1985 aient détruit prés de 60.000 ha de Pin maritime en Aquitaine.

Les techniques de télédétection aériennes et spatiales (Landsat TM, Spot) apportent désormais de nouvelles possibilités pour la surveillance systématique ou le chiffrage rapide des surfaces atteintes (RIOM 1984).

Enfin la mise en place d'un réseau de placettes d'observation permanentes devrait assurer une meilleure connaissance de l'évolution de la forêt et de son état sanitaire sur une longue période, permettant ainsi de remédier par anticipation à d'éventuels dépérissements d'origine environnementale ou phytosanitaire . Les mesures lourdes ne seraient concentrées que sur deux ou trois placettes constituant le "noyau dur". (mesures bioclimatologiques et écophysiologiques, biomasses et minéralomasses) tandis que de plus nombreuses placettes satellites (30 à 40) permettraient d'avoir une image représentative de l'état de la forêt (croissance, aspect foliaire, état phytosanitaire).

3. CONCLUSION

L'intensification de la sylviculture a plus que doublé les rendements de la production de bois de Pin maritime durant les vingt-cinq dernières années. Le renchérissement du côut des interventions forestières et la stagnation du prix du bois ont tempéré l'enthousiasme inconditionnel des premières années pour le progrès technique. Une attention croissante et justifiée a concerné l'économie et la gestion de la propriété forestière. Dans le même temps, la sylviculture prenait mieux conscience des contraintes imposées par la qualité de sa production et la préservation des équilibres naturels.

Le recul du temps et ces nouvelles préoccupations amènent à mieux raisonner l'intensification, sans pour autant la remettre en cause.

Si récemment, la forêt landaise n'a pas été épargnée par les adversités (hiver rigoureux en 1985, scolytes en 1986 et 1987, sécheresse, incendies et processionnaires en 1989), les dommages enregistrés ne sont en rien l'illustration d'une prétendue fragilité des forêts cultivées. Les dégâts de froid ont concerné à plus de 95% des races ibériques inadaptées, introduites en France après les grands incendies de la période de guerre . La race locale a, quant à elle, très bien supporté ces températures exceptionnelles de - 20°C, et les génotypes les plus vigoureux se sont en moyenne montrés les plus résistants. A cette occasion, il a été expérimentalement démontré que, toutes conditions égales par ailleurs (station, âge, sylviculture), la fertilisation phosphatée accroissait la résistance au froid. Le drainage systématique et la densité du réseau de pistes forestières ont grandement facilité les opérations de traitement contre les scolytes ou la lutte contre les incendies de forêts. Par ailleurs la rentabilité de la forêt cultivée a permis au sylviculteur de consentir un effort financier plus important pour en garantir la perennité (pulvérisation aérienne de produits insecticides contre la processionnaire, participation financière à l'entretien d'un corps permanent de sapeurs pompiers forestiers...).

La sylviculture intensive produit des arbres mieux nourris, mieux entretenus et exploités plus tôt ; beaucoup de parasites de faiblesse sont ainsi évités.

Pour conforter les investissements industriels en cours et améliorer la rentabilité de la production du bois, l'intensification de la sylviculture se poursuivra dans les décennies à venir. Le progrès génétique tant annoncé commence enfin à arriver en forêt. Les gains de productivité en volume et en rectitude (15 à 50% suivant les variétés) sont démontrés par les tests et déjà payés par la recherche publique ; eu égard aux résultats escomptés, l'utilisation des variétés sélectionnées ne devrait donc pas grever lourdement la trésorerie des sylviculteurs. Grâce aux études de nutrition minérale, la fertilisation va se rationaliser, pour une meilleure rentabilité des investissements réalisés et une meilleure qualité des bois produits. L'étude préalable du fonctionnement écosystématique de la forêt cultivée intensive évitera les erreurs à grande échelle, de même qu'un observatoire permanent de la forêt landaise signalera suffisamment à l'avance les dysfonctionnements ou les attaques parasitaires à prévenir ou à combattre.

On peut parier sans risque sur la poursuite de l'intensification de la sylviculture du Pin maritime dans les Landes de Gascogne, c'est un exemple utile pour d'autres espèces et d'autres régions.

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PLANTATION FORESTRY IN WESTERN CANADA

Denis P. Lavender

Professor and Head
Forest Sciences Department

University of British Columbia
Vancouver, Canada

FDC : 232: (71)

SUMMARY

A consistent program to artificially regenerate forest lands in western Canada did not begin until after World War II. Since that time there has been a steady growth, particularly in British Columbia in the numbers of seedlings planted, the area given site preparation treatments, and the number of plantations receiving post-planting vegetation management. This silviculture has been supported by research designed to develop efficient seedling production and planting scenarios and to estimate and implement the site preparation necessary to permit optimum plantation development. These efforts have been greatly stimulated by joint agreements between the federal and provincial governments to fund the silviculture necessary to return non-restocked backlog lands to full production. Nonetheless serious questions with regard to seedling production and vegetation management remain to be solved.

Keywords: Reforestation, seedlings, site preparation

INTRODUCTION

The forests of Canada west of Ontario are both very large in area and in variation, ranging from the stands of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Rafn.) Sarg.), western red cedar (*Thuja plicata* D. Don), Pacific silver fir (*Abies amabilis* (Doug.) Forbes) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) which dominate the maritime forests of coastal British Columbia to the boreal forests of the prairie provinces dominated by white (*Picea glauca* (Moench.) Voss) and black (*Picea mariana* (Mill.) B.S.P.) spruce, and lodgepole (*Pinus contorta* Dougl.) and jack pine (*Pinus banksiana* Lamb.) (Rowe, 1972). This paper will review briefly the history of reforestation in this area, trace the development of seedling production technology and site preparation methodology, discuss major problems encountered in stand establishment projects, and suggest current constraints to plantation success.

HISTORY

The first forest nursery was established in British Columbia in 1930; the first plantation, planted in 1932 (Knight, 1990). However, from this early beginning, the growth of artificial regeneration in British Columbia (Table 1) was very gradual with planting confined largely to coastal areas until the mid-nineteen sixties. Nonetheless, this period did see the first serious commitment to reforestation with the passage of the silviculture amendment to the Forest Act in 1948. A brief period of direct seedling trials after World War II demonstrated that, unless an effective rodent repellent were applied to the seeds, they would be destroyed by small mammals. When endrin, the only successful repellent (Dick *et al.* 1958) was banned, interest in direct seeding Douglas-fir in coastal B.C. declined.

The artificial reforestation program in the interior of British Columbia began in the 1960's utilizing primarily bare root lodgepole pine and spruce seedlings grown in coastal nurseries. In 1967, the Red Rock nursery in Prince George was opened to provide locally grown stock for the Prince George region. The planting program in the interior grew rapidly during the period 1965-1990, with a great increase in numbers of container grown seedlings (Table 2) and the development of many private nurseries.

The development of container-grown stock in British Columbia began with the evolution of the Jack Walters' bullet (Walters, 1961) followed by the development of the styroblock design into the several configurations currently used in British Columbia (van Eerden and Gates, 1990).

The great increase in artificial regeneration of denuded forest lands in British Columbia in the past twenty five years (Table 1) has seen the following major changes in the emphasis of this effort: a) production of planting stock has shifted from almost exclusively bare root Douglas-fir employed to establish coastal plantations to production of largely container grown seedlings, predominantly white and Engelmann spruce (*Picea engelmanni* (Parry) Engelm.) and their hybrid and lodgepole pine, planted in the interior; c) a restructuring of the forest nursery industry from an exclusively ministry function to a primarily private business; and d) transfer of the responsibility for reforestation from the provincial government to the companies conducting the forest harvest.

The forest resources of the prairie provenances have not been harvested as intensively as those of British Columbia (Table 3) and, hence, as the data in Tables 1 and 2 indicate, there has been much less reforestation in boreal forest region (Rowe, 1972). Nonetheless, there has been the same pattern of increasing concern for the regeneration of forests beginning shortly after World War II with signing of the First Forest Management Agreement in Alberta in 1955 and the subsequent development of the Quota Policy in 1966. These actions have required that all harvested areas in Alberta be regenerated within ten years of logging and represent, perhaps, the most progressive reforestation legislation in Canada.

Although the majority of the forests of the prairie provinces are classed as boreal (Rowe, 1972), there are distinct differences which have impacted reforestation programs.

In Manitoba and Saskatchewan, which are characterized by an extreme, relatively dry continental climate, the major tree species are aspen (*Populus tremuloides* Michx), black spruce and jack pine, which make up approximately one third, one quarter,

and one fifth of the stand volume, respectively. White spruce is a minor component and lodgepole pine is absent. In contrast, much of northern Alberta supports a mixed wood forest in which aspen, balsam popular (*Populus tacamahaca* Mill.) and white spruce predominate while extensive stands of lodgepole pine are found along the Rocky Mountains.

The foregoing differences have been reflected by differences in development of reforestation programs. In Manitoba and Saskatchewan, where cutovers are characterized by relatively shallow (eight centi[illegible]eter) organic layers, controlled burns have produced favorable sites for both planting [illegible] seeding jack pine (Chrosciewicz, 1988, 1980, 1978, 1976), whereas in Alberta the heavier organic layers characteristic of many sites have required different treatment. Here controlled burning is not used to any appreciable extent and site preparation equals scarification with anchor chain drag scarifiers or, more recently, "shark-fin" barrel scarifiers. Or, in areas of very heavy duff layers, treatment with plows is prescribed (Ferdinand, 1983).

In common with other regions of Canada, the 1960's saw a number of trials of different designs for production of container grown seedlings in the prairie provinces. In Alberta the Ontario-type tube was the principal system employed in the early sixties (Glade, 1972, Ferdinand *et al.*, 1974), but development of the Spencer-Lemaire fold-up tray resulted in conversion to this system (Luchkow, 1982). Saskatchewan also tested a number of container designs, including the Ontario tube, Spencer-Lemaire and the B.C./C.F.S. styroblocks (Flavelle, 1972) but settled on the FH 408 paperpot (Price, 1982), while in Manitoba, early trials utilized Ontario type tubes and Japanese paper pots (Gilmore, 1972) and later work, the FH 408 paperpot (Yarn, 1982).

The reforestation conducted during the period reviewed in the foregoing has produced a significant area of successful plantations, but a number of problems, both singly and in combination, have frequently caused unacceptably high mortality. Among these are: a) difficulties in regenerating Douglas-fir at higher elevations in the coastal mountains of British Columbia (Smith, 1978) and in the transition zone between the coastal mountains and the interior plateau in southern British Columbia; b) low soil and air temperatures and competing vegetation constraints on spruce plantations throughout the interior of British Columbia; c) small mammal damage, particularly white footed deer mice (*Peromyscus*), vole (*Microtus*), squirrel (*Citellus*) and hare (*Lepus*) to coniferous seeds and seedlings throughout British Columbia and in parts of the prairies provinces; d) constraints of high water tables and fine textured soils upon seedling growth in the Peace River area of British Columbia and Alberta; e) intense competition from deciduous species which threaten established spruce plantations in Alberta (Drew, 1988); f) seedling desiccation resulting from extreme drought conditions in prairie provinces and the southern interior of British Columbia; g) frost and desiccation injury from low temperature events throughout the year; and h) less than optimum logistics, stock quality, stock handling and planting throughout western Canada.

CURRENT REFORESTATION

Reforestation in British Columbia, has benefited greatly, particularly in areas of non restocked backlog lands, by shared cost programs between the Federal government and the province. The latest such agreement, the Forest Resource Development Agreement, provided three hundred million dollars between 1985 and 1990 to fund site preparation and planting projects, and reforestation extension and research. As a result,

plantation establishment has expanded dramatically (Table 2) with a projected three hundred million seedlings to be planted in 1990 (Mitchell *et al.*, 1990). And in Alberta numbers of seedlings planted have increased from 1.5 million in 1980 to 18 million in 1989 (Konowalyk, L. and Fast, W., 1989). However, this expansion has been accompanied by significant problems in quality control in all phases of the reforestation sequence (Brinkman, 1989). This lack of quality is a result of two general deficiencies. Until 1987, all aspects of reforestation were contracted through the Ministry of Forests which : a) was mandated to generally accept the lowest bid; and b) lacked the personnel to enforce quality reforestation. With the change in the Forest Practices Act in 1987, which assigns responsibility for establishment of free growing plantations to the companies which harvest the land, there is a likelihood of a more rigorous program.

The second deficiency, the lack of truly vigorous planting stock and effective site preparation, particularly in productive sites in the interior of British Columbia and in Alberta, has been the subject of greatly expanded research programs in recent years.

F.R.D.A. funded research has examined many aspects of seedling production including nutrition, rooting media, temperature and photoperiod regimes, and cold storage parameters. While such research has led to improvements in the reforestation scenario (Lavender, 1989, 1990), major questions with regard to production of seedlings capable of growing vigorously under the rigorous conditions often obtaining in the interior of British Columbia remain. Such questions include the nature of the effect of the nursery environment and the lifting, storage, shipping scenario upon the potential of seedlings to demonstrate the maximum stress resistance and to regenerate a "natural" root system promptly (von der Gonna and Lavender, 1989). But perhaps the major unsolved problem is that of designing a plantation establishment scheme which will permit optimum growth of a climax species such as white spruce in the environment of a clearcut.

Use of chemicals in site preparation in British Columbia is limited to 2,4-D, glyphosate, and velpar. Results of research involving these materials is reviewed in recent reports by Reynolds (1989), Butt (1989), and Hamilton and Watts, 1988. In essence, research has shown that these products can be effective in controlling competing vegetation but that characteristics of individual sites may limit such response. For example, effectiveness of velpar may be limited by soils with high organic content; glyphosate may control one species or population, but, because it has no residual action, allow invasion by other competitors; and the layer of dead vegetation created by herbicide may exacerbate potential for growing season frost damage.

Given the limitations of chemical site preparation in British Columbia and the ban on the use of chemicals in Alberta, both provinces have conducted research in site preparation utilizing large machines, some of which have been imported from Europe (Konowalyk and Fast, 1989, von der Gonna and Lavender, 1989; Breadon, 1987). Included in the trials were an assortment of plows, machines designed to produce discrete mounds of several configurations, patch scarifiers, and disc trenchers. Data describing seedling growth and survival of both lodgepole pine and white spruce seedlings in Alberta suggest that initial seedling survival and growth were favoured by planting in depressed patches but that after 3-5 years the greatest height growth was made by seedlings planted on mounds. An explanation offered was that moisture limited early seedling establishment but that later growth was favoured by the increased soil temperature and consequently nutrient availability on mounds. With any site preparation, areas with extremes of moisture suffered the highest mortality.

Similar trials in British Columbia were initiated in 1987. White spruce seedlings planted on raised microsites generally have grown more rapidly than seedlings planted in depressed or control microsites. Of some concern, however, is the general lack of vigorous root extension from the original plug, even after three growing seasons (Lavender, unpub.).

Reforestation programs in western Canada have benefited greatly from the dedicated efforts of competent foresters and the results of well designed, often ingenious research. However, if the forestry estate is to benefit maximally from stand establishment projects in the future, it should be recognized that the boreal forest types offer extreme obstacles to seedling survival and growth, that plantations require a prolonged period of maintenance if they are to be successful and, above all, that reforestation must be viewed as only the initial step in a long term silvicultural plan with the plantation establishment scenario predicated on long term, not immediate, considerations. It should be recognized, too, that the manpower currently assigned to both reforestation projects and research is grossly inadequate to produce the results required by society. Finally, there should be increased emphasis upon basic research. It is clear that only the techniques of advanced biological science are likely to solve the problems which still confront us.

Table 1: History of reforestation in western Canada

Province	Hectares Reforested (thousands)			
	before 1965 (total)	1965	1975-1980*	1984-1986*
British Columbia	164	22	60	101
Alberta	18	5	7	13
Saskatchewan	3	1	5	5
Manitoba	14	1	1	2

* average per year. All data to nearest one thousand hectares. (Cayford and Bickerstaff, 1967; Kuhnke, 1989)

Table 2: Seedling production

Province	Seedlings Produced per Year (1,000,000's) 1975			1985		
	Bareroot	Container	Total	Bareroot	Container	Total
British Columbia	62.9	17.9	80.8	55.0	137.0	192.0
Alberta (1978)	7.0	9.0	16.0	5.0	14.0	19.0
Saskatchewan	8.0	0.275	8.275	15.0	0.765	15.765
TOTAL	79.7	28.675	108.375	79.5	158.365	237.865

Table 3: Average area harvested in western Canada

Province	Hectares Harvested (thousands) 1975-76 to 1979-80*	1983-84 to 1985-86*
British Columbia	177	200
Alberta	22	32
Saskatchewan	19	20
Manitoba	19	15

* average per year. All data to nearest one thousand hectares. (Kuhnke, 1989)

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NEW STRATEGIES FOR NEW FORESTS
IN EASTERN CANADA

KEITH M. MCCLAIN AND KENNETH A. ARMSON

Research Scientist, Ontario Ministry of Natural Resources
Thunder Bay, Ontario, Canada

and

Forestry Consultant, Toronto, Ontario, Canada

FDC: 905.2: 906/907: (71)

SUMMARY

The current age class distributions of forests in eastern Canada point to wood supply deficits for the near future when industrial demands are considered. The importance of the woods industry to Canada's economy invokes the need to develop forest management strategies to ensure a continuous and economical supply of wood. Provincial strategies must be consistent with objectives and reflect the characteristics of the forest as a whole. Two strategies are described; the first advocates protection and harvest of overmature portions of the forest to meet immediate future wood requirements and the second strategy focuses on activities to increase the productivity of younger age classes of forests. This strategy requires commitment of the land owner to all aspects of forest management, particularly in the area of regeneration, tending, inventory, protection and the application of forest science.

INTRODUCTION

The future of the forest industry in eastern Canada is dependent upon rational utilization and management of the forest resource. Although harvest levels are a function of industrial requirements they must ideally, be supported by the productive capacity of the forest. Only in instances where this capacity has been increased through the application of silviculture should expansion in the forest industry be considered. As the forest sector enters an era of conservation, provincial concerns for sustainable development have prompted strategies to ensure the continued productivity of forests. Indeed, the health of the Canadian forest industry is contingent upon a unified effort to increase the sustainable level of forest productivity. In addition to indigenous factors that compel intensification of forest management, competition from tropical forest regions can be expected to increase. Statistics suggest that the average yield of wood in $m^3.ha^{-1}.year^{-1}$ ranges from an average of 1.0 for Canada to 60.0 for eucalypt (*Eucalyptus* spp.) plantations in the tropics (Day 1987). We must look not just to Scandinavian countries to gauge our success in forest management, but to our overall capability to compete within a global context.

The purpose of this paper is to provide an overview of factors that have lead to the development of strategic approaches to achieve a continuous long term supply of economical wood in the face of mounting evidence of provincial or regional shortages. This paper focuses upon that part of eastern Canada comprising the provinces of Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Quebec and Ontario. Much of the information presented was kindly provided by each of the provinces.

EARLY FOREST ACTIVITY

For a number of provinces the present forest estate can be linked to historical patterns of forest exploitation (MacKay 1985). To the earliest settlers forests were not considered an asset, but an obstacle to their existence. Forests were cut down and cleared with the use of fire. Settlements expanded and agriculture was established. Although early utilization of the wood cut was consumed to provide local building material, shipments of primary forest products were exported to France as early as 1667 for marine and other construction purposes. Later, blockades during the American War of Independence forced Britain to secure it's wood supplies for naval purposes from it's northern colonies. Soon afterwards the northern colonies became the preferred location to obtain wood when Baltic supplies were curtailed during Napoleon's war with Britain. Hence, by 1790 the timber trade was becoming well established as were industries such as ship building. Seemingly endless tracts of land were ultimately licenced to companies who sought white pine for masts and lumber. Exploitation was carried out at an increasing rate and was soon met with the implementation of regulations concerning cutting rights and protection from fire. Despite these regulations, harvesting continued with efforts devoted to maximizing profits with little or no concern for the perpetuation of the resource.

AREA AND OWNERSHIP

Table 1 shows the approximate area of productive forest land and ownership pattern for the six eastern provinces under consideration. Of the six provinces, New Brunswick has the greatest percentage of productive forest land relative to total land area and Newfoundland has the least. Quebec, followed by Ontario, has the largest land area of productive forest, but as a percentage of the total, both areas are nearly equal. Ownership patterns vary considerably. Newfoundland, Quebec and Ontario, the Crown owns greater than 85% of the total productive forest land only, whereas in Prince Edward Island 10% of the land is owned by the Crown. In New Brunswick and Nova Scotia 27% and 48%, respectively, of the land is owned by the Crown. Regardless of the ownership patterns provincial governments have the express responsibility of ensuring development of strategies consistent with management objectives. Indeed, the exploitation referred to above continued up until World War II and it wasn't until after, and in some cases not until the 1960's, that forest management practices were aimed at managing the forest resource on a sustained yield basis.

Table 1. Distribution of forested land of eastern Canadian provinces by ownership class.

Province	Area of Land	Area of Productive Forest Land	% of Total	Ownership of total forested land Crown	Private	Other
	-- 00 000 ha --			------ % --------		
Newfoundland	371	112	30	95	4	1
Prince Ed.Is.	6	3	50	10	90	-
Nova Scotia	53	38	72	27	70	3
New Brunswick	72	61	85	48	55	-
Quebec	1357	548	40	85	14	1
Ontario	891	383	43	88	10	2

Source: Anon. 1988.

FOREST PRODUCTS

Forest products have been the lifeblood of Canada's economy and still remain the single major commodity contributing to the country's net balance of trade (Figure 1). The contribution of the Atlantic provinces, Quebec and Ontario to the balance of trade in terms of forest products is presented in Figure 2. Consistently, Quebec has exceeded the value contribution of Ontario since 1978 and both provinces have individually exceeded the combined value contribution of the Atlantic provinces. Total roundwood consumption by province relative to the total country's consumption is presented in Figure 3. For Canada as a whole, the western provinces of British Columbia, Alberta, Saskatchewan and Manitoba were the major consumers of roundwood and contributors to the value of forest products exported and balance of trade. In 1985 total wood pulp exports to Britain and the United States represented 55% of the total export of this commodity, but for newsprint the proportion was 87%. Although, the destination of forest products such as, lumber and newsprint is primarily to the United States the market place is truly a global one.

THE FORESTS AND MILLS

The forest regions that exist throughout the eastern provinces are portrayed in Figure 4. By far, the greatest portion of forested land in the eastern provinces lies within the Boreal forest region followed by the Great Lakes-St. Lawrence, the Acadian and Deciduous forest regions. Black and white spruce, jack pine, balsam fir, white pine, poplar and birch predominate throughout the Boreal forest region. Soils in the Boreal forest and the northern Great Lakes St. Lawrence region are highly variable because of glaciation, but are typified by podzolic, luvisolic and brunisolic soils characterized by a wide range of texture and drainage. In the Great Lakes-

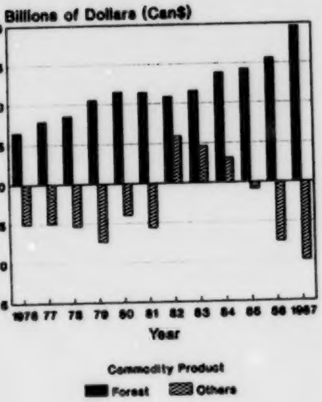

Figure 1.

Contribution of forest and other products (farm, fish, energy etc.) to Canada's balance of trade from 1976 to 1987.

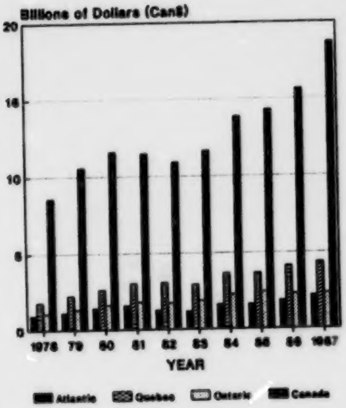

Figure 2.

Contribution of forest products from the Atlantic and other eastern provinces in relation to Canada's balance of trade from 1978 to 1987.

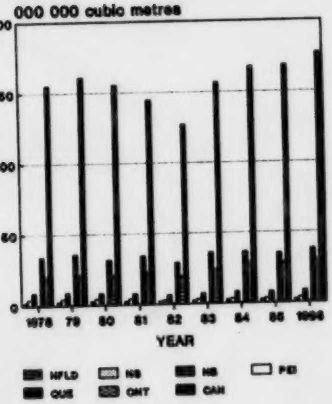

Figure 3.

Total roundwood consumption of eastern provinces in relation to Canada's total production from 1978 to 1986.

Source: Anon. 1989.

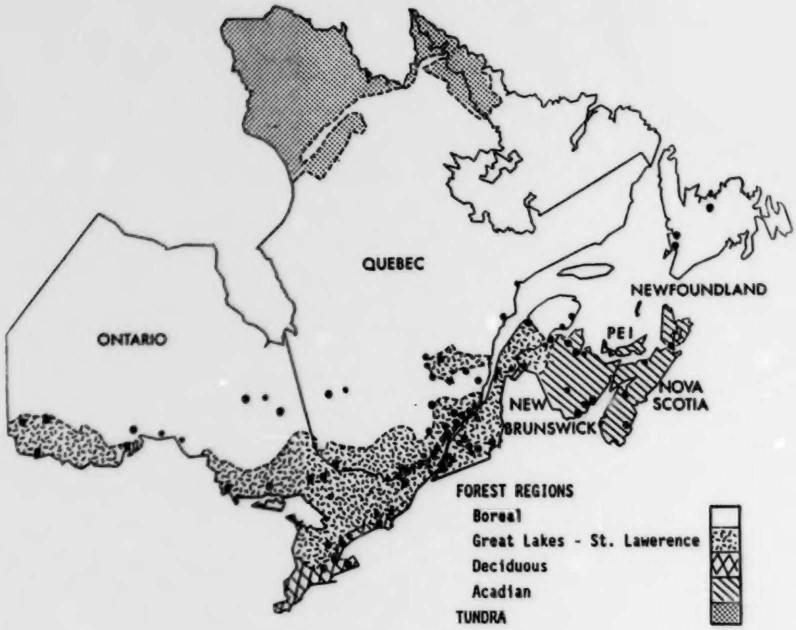

Figure 4. Distribution of forest regions in eastern provinces of Canada showing locations of major pulp and saw mill facilities.

St. Lawrence forest region mixtures of Boreal conifers and hardwood such as, maple, yellow birch, oak, largetooth aspen and beech exist in various combinations. In the northern areas of this forest region the diversity of southern hardwoods gives way to fewer species with trembling aspen and white birch being the principle components. The Deciduous forest region exists exclusively in southern Ontario and maintains considerable diversity in hardwoods on grey brown luvisol soils. Coniferous species are also present, but black spruce is commonly absent. The Acadian forest region contains red spruce, balsam fir, black spruce, white spruce and hardwoods such as, red oak, white elm, black ash, red maple, aspen and balsam poplar. Soils in this forest region are mainly podzolic.

The natural predominance of species, transportation routes, power and proximity to potential markets are contributing factors for the growth of industry in the Boreal and Acadian forest regions and can be expected to continue. Figure 4 shows the general location and concentration of major pulp and milling facilities throughout eastern Canada.

AGE CLASS

Any strategies for new forests have to take into account the distribution of the natural forest not only in terms of species. but also with respect to age class distributions as they will affect present and future wood supply. Sustained yield over a rotation requires that growth equals consumption and that ideally, annual harvest occurs over an equal area. There are, however, many factors that distort this ideal concept eg. losses due to fire, insect and disease. Age class distribution of all species combined on productive forested land is presented for each province in Figure 5. Clearly, future wood supply across the six provinces is dependent on an imbalanced age class distribution. Indeed, with the exception of Prince Edward Island, age classes are not evenly distributed in terms of percentage of the total forest area as well as on a land area basis.

In all provinces, except Ontario and Nova Scotia, significant portions of forested areas still remain unclassified. Although regeneration of harvested areas is an important component of forest management, the imbalance in forest age structure (and yield) requires the development of

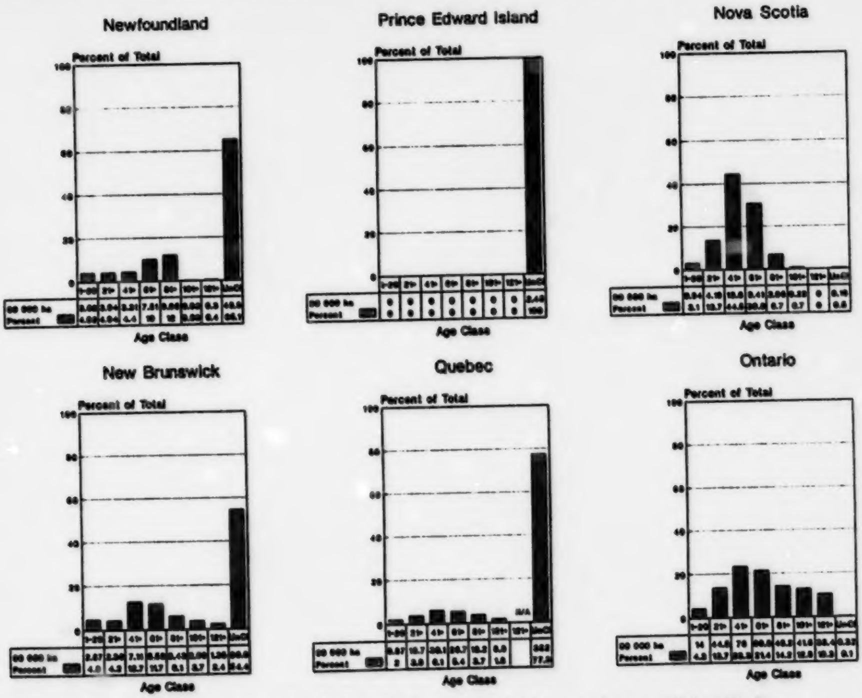

Figure 5. Age class distribution of forests (all species combined) by province expressed as percentage of total and land area. After Anon. 1988.

strategies that go beyond simple regeneration. They must embrace the forest resource as a whole through the consideration of the forest as a biologically sensitive production centre. Some parts of the forest can meet immediate needs while other parts can be expected to meet future requirements provided they are adequately managed. Strategies must be flexible and be constantly evaluated against objectives and conformity to biological and economical principles. In certain provinces and with species such as balsam fir and spruce, competing natural "harvesters" such as, the spruce budworm and fire significantly affect the wood supply and these also influence the development of strategies.

SPECIES

Jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*Picea glauca* [Moench.] Voss) and balsam fir (*Abies balsamea* [L.] Mill.) are the principle coniferous species of eastern Canada. Because these species are genetically diverse, individually, they can grow to commercial size over a wide range of soils and climatic conditions. Their silvical and genetic characteristics render them candidates for tree improvement and other intensive silvicultural practices. These species possess wood characteristics that make them particularly suitable for a multitude of uses. All species are used in the manufacture of lumber, but the long fiber lengths of spruce and balsam fir make these species particulary suited for the production of high quality papers (Bakuzis and Hansen 1965). Poplar (*Populus tremuloides* Michx.), a common intolerant hardwood species, is also utilized for the production of high quality paper for magazines and as an admixture with other pulp species (Panshin and De Zeeuw 1964). Jack pine is harvested primarily for use in the manufacture of pulp.

ENVIRONMENTAL CONSIDERATIONS

Increasingly during the past decade, societal and governmental concerns for the impact of forestry practices have acted to restrict the nature of many forest management practices. The most obvious of these have been limitations to the use of several legally permitted pesticides for control of vegetative competition and insects. The net effect of reduced use of these tools in forestry has been to lessen the chances of realizing management objectives of stand establishment and promote increased productivity. Despite the natural propensity of competing vegetation to outgrow crop species on most productive forest land, concerns over public health and damage to the environment generally prevail. Public concern has limited or in extreme situations, caused the abandonment of chemicals in the forest altogether. Resource managers must often seek alternatives to achieve forest management objectives. For example, *Bacillus thuringiensis* (B.t.), a biological insecticide, has gained favour over chemical insecticides in some regions in eastern Canada and is becoming more widely accepted by the public in the control of the spruce budworm (*Choristoneura fumiferana* [Clem.]).

Vegetation control still relies heavily on the application of herbicides, but their use is becoming increasingly constrained. Other methods such as hand weeding are too expensive to be cost effective.

Alternative practices to control the proliferation of competition have been examined in terms of method and timing of harvest and site preparation techniques. The aim is to shift site conditions to favour the establishment and growth of the crop trees and to diminish the early impact of potentially competitive vegetation.

Apart from obvious concerns over some forest practices, public perceptions regarding potential erosion and decrease in biological diversity are often difficult to address. It is perhaps unreasonable to expect that harvesting in any forest can be done without the occurrence of some physical and biological damage to the site. The intent of forest resource planning, however, is to keep the impact on forest site to a level where recovery is rapid, but this cannot always be assured. The effect of forest disturbance on wildlife has heightened public concern to the point where forest operations are seemingly controlled by desired characteristics of the habitat or cutover for wildlife. Certainly, from an industrial point of view, there may be additional costs for construction and maintenance of roads, harvesting and transportation to accommodate habitat requirements, but the public image of the industry is also important. Any approach to resource management planning must be with the understanding that the capability of the resource to be renewed be maintained and that the benefits derived from the resource must in the end be mutually beneficial. The setting of objectives by integrated resource management teams is thus becoming increasingly necessary and vital in the development of resource management for timber production. Full public understanding is required for continued support in this regard.

Another area of environmental concern relates to the impact of acid precipitation and climatic change, specifically the increase in atmospheric concentration of carbon dioxide (CO_2) and temperature. Existing forest strategies do not appear to have taken these phenomena into account. Interestingly, however, based upon the silvical characteristics of the species being discussed, it has been suggested that some conifer species may to be able to cope, if not thrive, with increased concentration of atmospheric CO_2 and anticipated increases in global temperature (Pollard 1989). However, we must not be complacent about such responses by thinking we stand to witness a passive increase in forest productivity if environmental conditions change. Quite the contrary could occur; mismatch between species within forest regions and the climatic environment they occupy may make forest areas vulnerable to the devastating effects of fire, insect and disease (Pollard 1989).

More subtle ecological changes are likely to occur with increased temperature as northern ranges of competitive broadleaved species slowly advance and necessitate intensification of already scant vegetation control programs. Moreover, implications due to physiological X environmental interactions may also arise that will preclude normal growth let alone increase productivity. For example, in the Pacific-Northwest and the southern coastal region of British Columbia lowered productivity of coastal Douglas-fir is feared under future warming trends because chilling requirements may not be sufficiently satisfied to ensure vigorous growth. Long term strategic forest planning must be prepared to accommodate alterations to forest productivity on a large scale. Further estimates have been made as to the intensity of effort that would be required for forests

to reduce increases in CO_2 (Sedjo 1989), but counter to this world problem are the potentially diminutive effects of air borne emissions of sulphur dioxide, nitrogen oxides, hydrocarbons and heavy metals on forest growth. Rennie (1989) presents data that suggest each of the provinces under consideration is wholly or partially the recipient of wet acid sulphate and wet acid nitrate deposition. Estimates of 20 $kg.ha^{-1}.year^{-1}$ have been made for wet deposition in south western Ontario to which another 25% must be added for dry deposition entrapped by the forest canopy. The exact nature of forest growth and changes in soil chemistry that attend atmospheric pollution have not been quantified for eastern Canada, but undoubtedly effects have been shrouded and described in terms of dieback and decline. Future effects are impossible to predict because there are difficulties in distinguishing between natural occurrences and damage caused by air pollutants.

STRATEGIES FOR NEW FORESTS

Despite expanded regeneration programs and practices in the eastern provinces future wood production will be dependent upon the existing growing figurestock and its inherent variable age class structure. Although this will vary by species and location, in general, there will be reduced production over the next few decades due to rather significant imbalances in age classes of present stands (Figure 5). Already, strategies are being devised, as far as possible, to meet the industrial demands by protecting the harvestability of older age classes and increasing the productivity of younger age classes by precommerical thinning. Such actions, in the absence of catastrophic events could allow for some adjustment in age class distribution and concentration of harvesting in a single age class rather than in multiple age classes. We believe, therefore, that in the eastern provinces, and perhaps elsewhere, this initial approach is key to ensuring future wood supplies. It is, however, only the first step.

STRATEGY: Protection and Harvest of Overmature Forests

Either on a provincial or more likely, a regional basis, wood supply deficits for the immediate short to long term have been identified across eastern Canada. This situation may be attributed to losses from insects and fire. As illustrated in Figure 5, age class distributions of the forests in general are not structured to provide sufficient wood volume on a sustained yield basis for specific future time periods. This has necessitated the need to protect overmature timber resources from loss by a host of agents such as, insects (eg. in northwestern Ontario, New Brunswick and Quebec against the spruce budworm and the hemlock looper (*Lambdina fiscellaria fiscellaria* [Gn.]) and fire. Provided adequate access is available these stands serve to provide the necessary wood requirements, either entirely or partially, depending upon availability of wood in an ideally harvestable age class. Figure 6 exemplifies the age class distribution of jack pine and black spruce in Ontario. Black spruce predominately occupies older age classes, necessitating the need to harvest these classes to satisfy industrial wood requirements. Jack pine, on the other hand, has a majority of growing stock in the middle age class with declining areas in younger and older age classes. In such circumstances lesser amounts of the older age class would

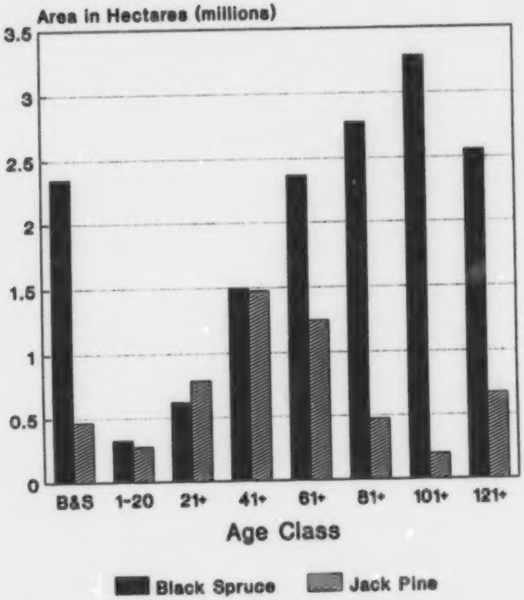

Figure 6. Age class distribution of black spruce and jack pine in Ontario. After Forest Resources of Ontario 1986.

be required to be harvested in favour of middle age classes.

In any case, the short term supply of wood can be coordinated by the judicial utilization of older age classes followed by regeneration. Cuts must be gauged in terms of a overall wood supply projection. The duration and quantity of cut should be coordinated such that there is an overall improvement in the distribution of age classes and that there is a migration in harvest toward the preferred age class (designated rotation age). Cutting in overmature forests also must not predicate against efforts to regenerate these stands and increase the area of regenerated forest land. Within the context of another forest initiative, prime site management, selection of the overmature stands to be protected and harvested should be considered with future productive capability in mind.

STRATEGY: Increasing Forest Productivity

The second strategy is one that embodies all the principles of forest management administration, silviculture and application of forest science. The first strategy was to protect and harvest, as required, the overmature forest. In doing so immediate expected wood deficits are managed, but there is little opportunity to increase productivity. Specific actions within the strategy to increase and maintain forest productivity have been initiated

and applied in relation to the unique circumstances of the forests and objectives of management. The eastern provinces accept the need to increase productivity of younger age classes and maintain it. Commitment to this objective has been made.

The success of maintaining productivity is directly linked to the early establishment of new forests. In all provinces forest nursery stock is planted. In some provinces, considerable investment is made annually in the production of bare root and containerized seedlings. In 1987, the production of containerized (seeded and clonal) seedlings in Ontario exceeded 79 million seedlings and was greater than 200 million seedlings in Quebec (Margolis 1988). The establishment of stands is, however, not solely dependent on planting as some harvested areas are left to regenerate naturally and significant areas are direct seeded. But in some instances, these two methods require later attention by thinning and spacing to provide optimum utilization of site resources. One of the principle methods of increasing the productivity of young stands is to conduct precommerical thinning. This technique is practiced in Newfoundland (44 000 ha from 1979 to 1989), Prince Edward Island (naturally regenerated hardwood stands), Nova Scotia (17 410 ha from 1986 to 1988) and large naturally and seeded areas of jack pine in northwestern Ontario.

Monitoring procedures are required for evaluation of response and comparison against objectives. Coupled with other information systems there can be a continual flow of information that can be used to project future wood yields using appropriate models. With the economics of any investment constantly under review, it is prudent to take steps to achieve maximum return within given constraints. Deciding what and where to invest in silviculture can greatly be aided by classification systems that categorize the productive capacity of forest sites. Prime site management considers the inherent productive capacity of the forest site is central to the success of silvicultural activities (Towill and Sims 1988). Managing prime sites closest to the mill will provide the most economical supply of future wood (Miller 1987, Teskey 1986).

Forest genetics and tree improvement have immense potential to increase the productivity of future forest stands. By breeding and selection of desired properties of forest products can be attained. Biotechnology also offers vast potential to produce trees that possess site specific characteristics. Genetically engineered trees that could endure, for example, cold soils would provide much opportunity to improve productivity in northern temperate forests. Furthermore, under threat of climatic change, biotechnology and its application to tree physiology has a prominent role in mitigating potential losses in productivity due to changes in the environment.

The merits of forest research can only be realized if they are packaged in a fashion that can be easily unwrapped and applied in the field with success. The need to apply more of what we know becomes increasingly critical as greater demands are placed upon the environment. This does not mean that technology can solve all the issues before us, but misapplication of technology or no application of technology when the opportunity exists represents a potential economic loss. Therefore, a mechanism to evaluate science, existing technology and undertake development and communicate to

users (policy makers and forest managers) is and will be critical as we face increasing constraints in the management of forests as components of ecosystems.

CONCLUSION ON THE NEED FOR NEW STRATEGIES

The appropriateness of the native species in the existing forest to new management strategies means that introduced species will not play a role in the new forest. One other native species, tamarack (*Larix laricina* [Du Roi] K. Koch) which is not presently used significantly may be planted in certain forest areas in the future. This is because of its rapid growth, genetic diversity and ease of vegetative propagation.

The rapid increase in the use of computers, models for timber supply and other resource values and the installation of geographic information systems (GIS) means that strategy options can be considered in a quantifiable way and to a degree that has not existed in the past. One of the most important results of these technological advances is that they can be coupled with our knowledge of natural resources, particularly the linkages and relationships between forest and timber management practices and the management of the other resources and values.

As strategies are put into place the need for increased research and development, in particular, the ability to transfer knowledge and expertise rapidly and effectively will be required.

The real world of eastern Canadian forests is such that any strategies which do not attempt to provide alternatives in the face of known types of recurring factors such as, fire and insect attack will be of questionable value. They must also take into account the dynamics of a society which is largely urban, with little actual knowledge of forestry as it is presently practiced. This society, whose perceptions are based to a large extent on myths and half-truths, is however, where many of the decisions will be made which can expedite, constrain or repudiate new forest strategies. The strategies to deal with this are, perhaps, the most important ones the forestry community has yet to develop.

It is increasingly evident that the strategies employed in forest management must change dramatically to enable the manipulation of the forest in order to bring about a juxtapositioning in time and space of forest stands. These arrangements must not only provide a continuous and predictable supply of timber at economic prices, but also ensure that the other desired resources and values can be addressed and retained (Harris 1984).

There are, therefore, essentially three steps in the development of new strategies:

1. Establishment of strategies to ensure a continuous and predictable supply of wood from the existing forest. This is currently the major focus with implementation of associated practices such as precommercial thinning and other tending practices.

2. From the knowledge of the land base in addition to that of the forest, together with the setting of quantifiable objectives for species timber supply, there is a "prime land" strategy to ensure that the future wood supply will be available at economically acceptable levels.

3. In order to satisfy both the need for wood, which for Canada as a whole, let alone eastern Canada, is the economic base for forest management, and the demands by society for non-timber values there is a third step. This can only be integrated into an overall strategy when the first two have been established. It involves the decision-making in the allocation of silvicultural activities, especially, but not exclusively, harvesting.

These three steps do not necessarily occur sequentially either in time or space. Emphasis on the first two will depend upon the forest and conditions at provincial and local levels. Implementation of the third step is very much dependent on the availability of technology such as geographic information systems (GIS) as well as models which provide for ongoing analysis and review of cause and effect relationships. The manner in which these steps are implemented is particularly critical on public lands if they are to be accepted as necessary to the achievement of sustainable development in the long run.

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DESTRUCCION DE LOS ECOSISTEMAS FORESTALES DE AMERICA CENTRAL. ACCIONES NECESARIAS PARA CONSERVAR EL GERMOPLASMA

Dr. Rodolfo Salazar

Forest Geneticist
Madeleña Project
CATIE, Turrialba, Costa Rica

FDC: 165.3: 907: 914: (728)

RESUMEN

Se presenta una revisión sobre la riqueza y la diversidad genética del componente forestal de América Central y sobre el acelerado proceso de destrucción que continua enfrentando tanto el bosque de coníferas como de latifoliadas. Se discuten alternativas de conservación y el importante papel que juegan las áreas protegidas en la protección del germoplasma de cientos de especies sobre las que se desconoce su verdadero potencial. La reforestación en la región debería jugar un papel muy importante en la conservación, pero todavía continua en un nivel poco significativo como para que se le pueda considerar como una herramienta importante en la protección del recurso forestal de América Central.

INTRODUCCION

La región centroamericana de la cual forman parte Guatemala, Belice, Honduras, El Salvador, Nicaragua, Costa Rica y Panamá, se ubica entre los paralelos 7°N y 18°N. Tiene un área de 508 944 km^2 que corresponde a un 2.5 por ciento del resto del Continente Americano.

Como consecuencia de la topografía accidentada y por estar ubicada entre dos océános, el clima de esta región se caracteriza por presentar muy variadas condiciones, que van desde sitios áridos con una temperatura promedio de 24°C y 400 mm de precipitación anual, hasta sitios muy húmedos con 28°C de temperatura y 7500 mm de precipitación. También predominan las altas montañas donde la temperatura media es de aproximadamente 4.5°C como en el Cerro Chirripó en Costa Rica. La topografía es bastante irregular, existen grandes llanuras a lo largo de la costa pacífica y atlántica; la región central está atravesada por cadenas montañosas bastante accidentadas que son prolongaciones de la Sierra Madre. La mayoría del territorio se encuentra a elevaciones superiores a los 500 msnm (Leonard 1987).

Esta diversidad climática y topográfica (Cuadro 1) ha permitido la

formación de por lo menos 20 zonas de vida, caracterizadas por una diversidad florística que en algunos casos se traslapa entre zonas de vida aledañas (Leonard 1987).

Esta diversidad florística a lo largo y ancho de la región, como ya se indicó, se desarrolló sobre diversas condiciones climáticas y sobre suelos frágiles de origen volcánico, como en el altiplano de Guatemala y la Meseta Central de Costa Rica o sobre suelos calcáreos de origen marino como en el Petén de Guatemala o sobre suelos de origen aluvial como en la mayor parte del Darién en Panamá.

En 1986, América Central tenía una población de 25 millones de habitantes, con una tasa de crecimiento de 2.8 por ciento anual. Este crecimiento poblacional, aunado al tradicional uso destructivo del recurso bosque como único mecanismo para colonizar y definir el derecho de propiedad de la tierra y la falta de una política de uso racional del suelo, son los responsables de haber llevado a los países de la región a un verdadero desastre natural.

Cuadro 1: Algunas características de los países centroamericanos (Leonard 1987)

PAIS	AREA (km^2)	PRECIPITACION ANUAL (mm)	TEMPERATURA MEDIA ANUAL (°C)	ZONAS DE VIDA* (N°)	POBLACION EN 1986	INCREMENTO ANUAL (%)
Guatemala	108889	500 a 6000	15 - 25	11	8.600.000	3.1
Belice	22965	1300 a 4450		6	159.000	2.5
Honduras	20877	1500 a 2300	18 - 25	8	5.100.000	2.4
El Salvador	112088	1500 a 3000	16 - 28	8	4.600.000	3.2
Nicaragua	140746	400 a 6300	23 - 30	11	3.300.000	3.4
Costa Rica	50700	1300 a 7500	14 - 28	19	2.700.000	2.6
Panamá	77060	1500 a 5500	19 - 28	12	2.200.000	2.1
Total	533325				25.250.000	2.8

* Zonas de vida sistema Holdridge

DESTRUCCION DE LOS ECOSISTEMAS NATURALES

La diversidad ecológica que caracteriza a América Central le ha permitido desarrollar una muy rica diversidad florística en los distintos ecosistemas, al punto que se la considera como la más importante del mundo (Hartshorm 1978).

La historia indica que casi toda el área de América Central estuvo cubierta por bosques; no obstante, ya para 1970 sólo el 49 por ciento del área

total tenía cobertura boscosa y 10 años despúes en 1980 sólo existía el 41 por ciento, el Cuadro 2 resume las áreas con cobertura boscosa por país (Leonard 1987).

Cuadro 2: Cobertura boscosa en Centroamérica hasta 1970 y 1980 (Gartshon 1984, Leonard 1986)

PAIS	AREA BAJO BOSQUE			
	1970		1980	
	(km^2)	(%)	(km^2)	(%)
Guatemala	51.000	47	45.500	42
Belice	10.470	46	10.120	44
El Salvador	18.000	9	1.400	7
Honduras	48.800	44	40.600	36
Nicaragua	56.200	47	44.800	38
Costa Rica	25.670	51	18.300	36
Panamá	44.700	59	41.700	55
Total	254.840	49	202.420	41

Esta riqueza florística, como el rango de variación genética que muestran las especies, se puede interpretar como la respuesta al proceso de colonización y adaptación de los organismos a las variadas condiciones de clima y suelo. Hartshorm citado por Leonard (16) menciona que en la Estación Biológica de la Selva en Costa Rica, que tiene únicamente un área de 1.300 ha hay 1.5 veces más especies de plantas y animales que en el Estado de California. Los estudios recientes sobre la diversidad genética de algunos de los pinos centroamericanos (*P. oocarpa*, *P. caribaea* var. *hondurensis*, *P. tecunumanii*, etc.) que se extienden desde Guatemala hasta la parte central de Nicaragua, muestran claramente la existencia de una amplia variación genética entre las distintas fuentes de semilla, tanto en la morfología, como en el rendimiento (CAMCORE 1989, Guevara 1985).

Algunas de las pocas latifoliadas nativas de la región centroamericana, estudiadas a nivel internacional como *Leucaena leucocephala*, *Gliricidia sepium*, *Pochota quinata*, *Calliandra calothyrsus*, *Guazuma ulmifolia* etc, también han mostrado gran variabilidad genética a lo largo de su distribución natural.

De esta diversidad florística aún no se cuenta con estudios concretos que cuantifiquen el verdadero potencial de estos recursos naturales. En la mayoría de los casos, estos estudios todavía incompletos, se limitan casi exclusivamente a la identificación taxonómica de las especies y no a una verdadera valoración sobre el potencial de cada una de ellas, ni a valorar el grado de variabilidad genética.

Un ejemplo es Belice que en 22.965 km^2 han sido reportadas aproximadamente 700 especies de árboles, representados por 87 familias y 331 géneros

(Hartshorm 1984).

Holdridge 1980, indica que solo en Costa Rica existen alrededor de 1500 especies arbóreas. El Cuadro 3 puede dar una idea de la magnitud de la diversidad florística de la Región donde se reportan más de 100 familias de árboles.

Cuadro 3: Lista de familias de especies arbóreas de América Central

Acanthaceae	Escalloniaceae	Oleaceae
Actinidiaceae	Euphorbiaceae	Opiliaceae
Anacardiaceae	Fabaceae	Papaveraceae
Annonaceae	Fagaceae	Piperaceae
Apocynaceae	Flacourtiaceae	Polygonaceae
Aquifoliaceae	Garryaceae	Proteaceae
Araliaceae	Guttiferae	Quiinaceae
Avicenniaceae	Hamamelidaceae	Rhamnaceae
Betulaceae	Hernandiaceae	Rhizophoraceae
Bignoniaceae	Hippocastanaceae	Rosaceae
Bixaceae	Hippocrateaceae	Rubiaceae
Bombacaceae	Humiriaceae	Rutaceae
Boraginaceae	Icacinaceae	Sabiaceae
Brunelliaceae	Juglandaceae	Salicaceae
Burseraceae	Lacistemaceae	Sapindaceae
Caesalpiniaceae	Lauraceae	Sapotaceae
Capparidaceae	Lecythidaceae	Saxifragaceae
Caprifoliaceae	Loganiaceae	Simaroubaceae
Caricaceae	Loranthaceae	Solanaceae
Caryocaraceae	Lythraceae	Staphyleaceae
Celastraceae	Magnoliaceae	Sterculiaceae
Chloranthaceae	Malpighiaceae	Styracaceae
Chrysobalanaceae	Malvaceae	Symplocaceae
Clethraceae	Melastomataceae	Theaceae
Cochlospermaceae	Meliaceae	Theophrastacea
Combretaceae	Menispermaceae	Thymelaeaceae
Compositae	Mimosaceae	Tiliaceae
Cornaceae	Monimiaceae	Ulmaceae
Cunoniaceae	Moraceae	Umbelliferae
Cyatheaceae	Myricaceae	Urticaceae
Dichapetalaceae	Myristicaceae	Verbenaceae
Dilleniaceae	Myrsinaceae	Violaceae
Ebenaceae	Myrtaceae	Vochysiaceae
Elaeocarpaceae	Nyctaginaceae	Winteraceae
Ericaceae	Ochnaceae	Zygophyllaceae
Erythroxylaceae	Olacaceae	

Sólo en la década de los ochenta, la tasa de deforestación fue del ocho por ciento. Se estima que en la actualidad menos del 40 por ciento de la

región está cubierta por bosques y se deforesta aproximadamente 400 mil hectáreas por año (Cooley et al. 1981).

Como se sabe, las causas de esta destrucción incontrolada son muy variadas, por ejemplo en Guatemala en 1982 la industria destruyó 234 mil m^3 de madera, de los cuales sólo 180 mil m^3 utilizó. Para esa misma fecha, el país consumió 13.064.000 m^3 de leña. Se estima que los incendios y plagas destruyeron 1.350.000 m^3 y que 6 millones de m^3 fueron destruídos en el proceso de colonización. Por estas mismas causas, se estima que de 1982 al año 2000, el volumen de madera en pie será reducido de 22 millones a 17 millones m^3 aproximadamente (Cooley et al. 1981, URL/AID 1984).

Para 1985 en Nicaragua se estimaba la existencia de 4.4 millones de hectáreas de bosques naturales, de estos el 9 por ciento son coníferas. Como consecuencia del avance de la frontera agrícola se estima que para el año 2005 serán eliminadas 404 000 ha de bosques naturales. En este país de los 7.5 millones de m^3 que se cortan anualmente, sólo 1.4 millones son aprovechados (80% como leña), el resto no son utilizados (INTERFORES 1985, Sola 1989).

El caso de Honduras es particularmente distinto, ya que la explotación del bosque natural constituye uno de los principales rubros de la economía nacional, la madera es uno de los cinco productos principales de exportación. Esta actividad está soportada por la existencia de 7.4 millones de hectáreas de bosques, de los cuales 40.5 por ciento son coníferas que tienen un amplio mercado nacional y ocupan el 97 por ciento del volumen exportado. No obstante la importancia del componente forestal para la economía nacional, se estima que entre 1977 y 1981, las quemas ilegales destruyeron un promedio de 80 mil hectáreas, principalmente de coníferas, con una pérdida aproximada de 448 mil m^3. El bosque de latifoliadas también está siendo reducido en un 4 por ciento anual (80 mil hectáreas), para convertir las tierras en potreros y áreas para cultivo (Campanella 1985).

Leonard (16) indica que Costa Rica para 1987 sólo contaba con 2.500 km^2 de bosques productores, pero que la mayoría de esta área se encontraba comprendida en áreas bajo distintos tipos de reserva, como se verá más adelante.

Como lo indican las estadísticas anteriores, en las últimas dos décadas, la riqueza florística de los países centroamericanos, ha sido sometida a un proceso de destrucción tan acelerado que ya en algunas de las formaciones boscosas, la destrucción es irreversible.

DESTRUCCION DEL GERMOPLASMA

Existen muchos trabajos aislados que describen en forma parcial la composición florística de los distintas zonas de vida; además, se sabe que existen muchas especies que aún no han sido descritas. Esto es un indicador claro de que el verdadero potencial de la gama amplia de especies forestales es desconocido; y que el uso de este recurso que está siendo destruído, ha estado concentrado en muy pocas especies que son las que tienen valor económico en la actualidad. Por ejemplo en los bosques de latifoliadas de

Guatemala se estima que existen más de 400 especies forestales. Unicamente en el Petén al norte del país que ocupa más del 66 por ciento del bosque de latifoliadas y donde se encuentran la mayoría de estas 300 especies, sólo *Cedrela adorata*, *Swietenia macrophylla*, *Roseodendron Donnell Smithii* y *Tabebuia rosea* entre otras son aprovechadas comercialmente (Figueroa et al. 1985, Flores 1984).

Aunque existen varios géneros de coníferas como *Pinus*, *Cupressus*, *Abies* y *Juniperus*, son pocas las especies del género *Pinus* que se comercializan, principalmente del *P. oocarpa*, *P. pseudostrobus* y *P. tenuifolia* (Figueroa et al. 1985).

Las coníferas ingresaron a México y América Central por la parte norte del hemisferio en la segunda mitad del período terciario Mirov (1967); y en su proceso de migración hacia el sur, llegaron hasta la parte central de Nicaragua, aproximadamente hasta el paralelo 12°. Durante todo este período y como consecuencia del proceso de migración y colonización de áreas ecológicamente distintas, se han ido desarrollando toda una serie de especies de coníferas, principalmente del género *Pinus*, que todavía hoy, se continúan describiendo nuevas especies.

El Cuadro 4 muestra una lista de las coníferas más importantes descritas hasta la fecha en América Central.

Cuadro 4: Coníferas centroamericanas (Aguilar 1942, Mirov 1967, Styles and Hughes, 1988)

ESPECIE	DISTRIBUCION	ELEVACION (msnm)
Pinus ayacahuite	GUA, HON, ELS	2300-3200
P. strobus var. *chiapensis*	GUA	1500-2000
P. montezumae	GUA	1500-2500
P. rudis	GUA	2300-4000
P. teocote guatemalensis	GUA	1300-2000
P. pseudostrobus	GUA, HON, ELS	1300-2000
P. tenuifolia	GUA	1100-2400
P. patula	GUA, HON, ELS, NIC	1500-2000
P. oaxacana	GUA	1500-2400
P. oocarpa	GUA, HON, NIC, BELICE	900-2400
P. caribaea var *hondurensis*	GUA, HOND, ELS, NIC, BELICE	0- 600
P. tecunumanii	HON, NIC, BELICE	400- 900
P. maximinoi	GUA, HON	3000
P. hartwegii	HON	280-3200
P. chiapensis	GUA	2850
Cupressus lusitanica	GUA, HON	2000-2800
Podocarpus guatemalensis	GUA, BELICE, HOND, CR	0-700
P. oleifolius	GUA, HON, ELS, NIC, CR	1500-2800
Taxus globosa	GUA, HON, ELS	2700
Juniperus comitana	GUA, HON	1500
Abies religiosa	GUA, HON, ELS	3000-4000
Abies guatemalensis	GUA, HON, ELS	2500-3000

De estas coníferas, *P. caribaea* var *hondurensis, P. oocarpa, P. pseudostrobus, P. tecunumanii, C. lusitanica* son los que se encuentran más representadas en distintas áreas de la región; y son las que en los últimos 20 años han sido más exploradas e investigadas a nivel del trópico mundial. Las características de excelente crecimiento y rendimiento que han mostrado fuera de sus sitios de origen (CAMCORE 1989, Guevara 1985), ha provocado un fuerte interés de algunas instituciones internacionales como el Oxford Forestry Institute (OFI) y Central American and Mexico Coniferous Resources Cooperative (CAMCORE), quienes han venido desarrollando exploraciones intensivas y recolectando semillas de las especies a lo largo de su distribución natural, para realizar los correspondientes estudios de procedencias y progenies en forma cooperativa en los países tropicales y subtropicales de América, Asia y Africa.

Por ejemplo el *P. caribaea*, una de las especies más investigadas ha sido colectada en los sitios mostrados en el Cuadro 5., donde se puede observar un rango latitudinal desde 17° N hasta 12°13' N y una variación altitudinal de 0 a 700 msnm, con precipitaciones de 912 mm a 4118 mm anuales. Ahora existen pruebas de procedencias y progenies en más de 30 países tropicales y subtropicales (Hartshorm 1978, Guevara 1985).

Situación similar ocurre con las otras especies apuntadas. En este momento se podría pensar que gran parte de este germoplasma está protegido ex-situ; no obstante, la empresa privada tiene gran interés en retornar a los sitios de distribución natural, para aumentar la base genética de las procedencias en estudio; pero se está enfrentando con el problema de que para algunas de esas procedencias los rodales naturales han sido destruídos, o están altamente erocionados como sucede con las procedencias de Poptun en Guatemala y Los Limones en Honduras.

PROTECCION DE ESPECIES EN PELIGRO DE EXTINSION

Como ya se ha indicado, la tasa de destrucción de bosques naturales en América Central es alta y continuará aumentando, hasta tanto no se modifiquen las políticas de tenencia y uso de la tierra, se de un control adecuado del crecimiento poblacional y se regule en forma eficiente el uso de la madera. Pero también es necesario ser realista y entender que las existencias actuales de bosques naturales no esperarán hasta llegar a tener estas regulaciones, y que lamentablemente desaparecerán si no se toman las medidas del caso.

Es urgente que a nivel nacional y regional se desarrolle una estrategia para conservar el germoplasma de coníferas y latifoliadas en las distintas formaciones ecológicas, para asegurar que la diversidad genética de las especies estudiadas y no estudiadas no desaparezca.

No es posible hablar únicamente de conservar especies en peligro de desaparecer, sino del germoplasma de esa diversidad genética del componente florístico en las distintas zonas ecológicas. Esto implica que cada país debe identificar áreas de bosque que sean representativas en cada zona de vida y convertirlas en reservas. Esta condición aplica principalmente donde existen todavía grandes extensiones de bosques naturales, tanto de latifoliadas como de coníferas que hayan sido poco disturbadas; como en algunas áreas del Darién en Panamá, La Mosquitia en Honduras, El Petén en Guatemala, etc.

Cuadro 5: Algunas de las procedencias de *P. caribaea* var. *hondurensis* que están siendo estudiadas (Guevara 1985).

PAIS	SITIO	LATITUD (N)	ELEVACION (msnm)	PRECIPITACION (mm)
Guatemala	Poptum	16°21'	500	1688
Belice	M. Pine Ridge	17°00'	400	2064
Belice	Las Lomitas	16°28'	30	2398
Belice	Silver Creek	16°40'	30-100	2297
Belice	Melinda	17°01'	10	2137
Belice	Sitios Pine Ridge	17°34'	20-40	1818
Honduras	Brus Lagoon	15°45'	40	2840
Honduras	Guanaja	16°27'	50-100	2308
Honduras	Las Lomitas	16°28'	30	2398
Honduras	Culmi	15°06'	500-600	1325
Honduras	Patosi	15°20'	100-700	1325
Honduras	Los Briones	13°34'	600	912
Honduras	Los Limones	14°03'	700	665
Nicaragua	Laguna del Pinar	12°13'	<10	4184
Nicaragua	Karawala	12°58'	10	3897
Nicaragua	Alamicamba	13°34'	25	2610
Nicaragua	Rio Coco	14°45'	12	2859
Nicaragua	Sillma Sia	14°45'	50-100	2863
Nicaragua	Kuakuil	14°12'		
Nicaragua	Santa Clara	13°48'	700	1818

Un aspecto positivo que ayuda a reducir este esfuerzo, es el hecho de que en América Central existen más de 51 parques (Cuadro 6) nacionales y otras áreas protegidas que abarcan un amplio rango de condiciones de clima y suelo. Estas áreas representan aproximadamente 5.5 millones de hectáreas (55047 km^2) lo que equivale a más de 10 por ciento del territorio centroamericano. Estas áreas de conservación aunque en principio fueron creadas para otros fines, también cumplen la función de conservar la diversidad florística y genética de la mayoría de las especies forestales de la región. No obstante existen muchas formaciones boscosas que por estar en condiciones de clima y suelo diferentes, tienen genotipos especiales que no se encuentran en las áreas protegidas y que también deben ser conservadas. Además, hay muchas áreas como en el altiplano de Guatemala, el pacífico de Costa Rica y Guatemala donde la presión demográfica y la tenencia de la tierra prácticamente han acabado con el recurso forestal, en estas condiciones es muy importante conservar ex-situ los mejores ejemplares que han quedado de las especies valiosas.

Cuadro 6: Areas protegidas de América Central (Morales 1988)

PAIS	PARQUES NACIONALES		RESERVAS FORESTALES		REFUGIOS VIDA SILVESTRE		OTRAS (ha)	TOTAL (ha)
	No	(ha)	No	(ha)	No	(ha)		
Guatemala	4	13.296			2	3.400	315.835	332.531
Belice	4	4.165	2	91.500	3	1.174	35.311	132.150
Honduras	14	170.271			11	65.100	71.234	831.705
Nicaragua	3	22.227	10	123.005	15	263.400		413.432
El Salvador								
Costa Rica	14	420.234	10	378.015	10	125.267	1142.232	1332.524
Panamá	12	1008.860	7	77.780	1	53	1095.369	2462.431
Total								5504.773

LA REFORESTACION COMO SOLUCION INMEDIATA A LA CONSERVACION

Hay que entender con claridad que el sector forestal siempre ha sido visto en América Central como un recurso natural del cual se puede hacer algún uso y nunca como una alternativa de producción basada en el manejo del bosque natural y en el establecimiento de plantaciones. No ha sido sino hasta los últimos años cuando se presenta un despertar de esta actividad, como resultado de los proyectos de investigación que se han venido realizando como el Proyecto de Leña y el Proyecto de Madeleña implementadas por CATIE/ROCAP[1]. También hay que entender que esta actividad tendrá un desarrollo más rápido, hasta que se pueda transferir al finquero un paquete tecnológico ajustado a las distintas condiciones y necesidades, que le asegure una ganancia sobre la inversión. Es necesario tomar en consideración la posibilidad de manejar los bosques naturales como una alternativa de protección y producción.

Son varias las causas responsables del poco interés del finquero por participar en el cultivo de árboles, entre las principales se pueden mencionar la falta de una legislación adecuada que fomente el desarrollo forestal, falta de financiamiento adecuado, desconocimiento por parte del finquero sobre la importancia del componente forestal en la finca y su potencial como fuente de producción; y finalmente la falta de experiencias concretas sobre las especies con potencial y sistemas de manejo e industrialización por parte del personal técnico.

Los trabajos ex situ que realizan CAMCORE y el OFI así como las actividades de reforestación son alternativas positivas pero que cubren una proporción muy baja del potencial total.

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[1] CATIE - Centro Agronómico Tropical de Investigación y Enseñanza
ROCAP - Regional Environmental and Natural Resource Management Project

Este despertar por el cultivo del árbol está provocando modificaciones importantes en la legislación de cada país, quienes están destinando recursos económicos para impulsar la actividad, fundamentados principalmente en las experiencias que se han venido obteniendo en los últimos años tanto con especies nativas como introducidas.

En la medida que esta actividad logre desarrollarse, la protección de la riqueza florística que queda estará menos expuesta a desaparecer, tanto porque se empieza a comprender el verdadero potencial de dichos recursos, como porque la producción de las plantaciones reducirá la presión sobre los bosques naturales; además, el hecho de que se están considerando cada vez más especies nativas también permitirá ir conservando la riqueza de estas especies a través del establecimiento de plantaciones, como ocurre con las especies: *P. caribaea* var. *hondurensis*, *P. oocarpa*, *P. tecunumanii*, *C. lusitanica*, *B. quinatum*, *G. sepium*, *C. alliodora*, *Sterculia apetala*, *Albizia guachalepe*, *Alnus acuminata*, *Bochycia hondurensis*. El número de especies nativas que están siendo utilizadas para reforestar es realmente insignificante al compararlo con la diversidad florística de la región, esto es realmente un problema ya que muchas de estas especies llegarán a desaparecer antes de que se llegue a conocer su verdadero potencial.

El cultivo, a nivel comercial, de especies exóticas como *Gmelina arborea*, *Tectona grandis*, *Eucalyptus deglupta*, *E. grandis*, etc., está siendo impulsado y ya están empezando a ser aprovechadas en la producción de madera aserrada, poste y leña a lo largo de la región.

No obstante, para que el cultivo de árboles se convierta en otra alternativa de inversión, se requiere de mayor apoyo económico y técnico, que permita demostrar el verdadero potencial de la actividad forestal para los países de América Central. No hay que olvidar que actualmente la región tala más de 400 mil hectáreas por año y que difícilmente se están reforestando más de 25 mil hectáreas por año.

En conclusión, es urgente que se comprenda el riesgo que enfrentan los recursos forestales nativos de la región y que deben iniciarse las acciones necesarias para cuantificar este potencial y conservarlo. Es importante y prioritario ir incorporando cada vez más las especies nativas en los programas de reforestación; y que se dediquen recursos de organizaciones internacionales para proteger y manejar la biodiversidad forestal de la Región.

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MANAGING SOUTHERN PINE PLANTATIONS FOR WILDLIFE

Ronald E. Thill

Supervisory Research Wildlife Biologist
U. S. Forest Service
Southern Forest Experiment Station
Wildlife Habitat and Silviculture Laboratory[1]
Nacogdoches, Texas

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SUMMARY

This paper reviews available information on how intensive management of pine plantations affects wildlife in the southeastern United States. Practices discussed and evaluated in this paper include harvesting, site preparation, planting, thinning, burning, and fertilizing. Management of special habitat features (e.g., standing dead trees and down woody material) is also discussed.

When size, shape, and spatial distribution of clearcuts are considered, and frequent thinning and burning are practiced after pine canopy closure, intensively managed plantations furnish suitable habitat for many early-succession wildlife species--including key game species such as deer, quail, and rabbits. However, intensive even-aged pine silviculture is detrimental to those species requiring hardwoods, snags and cavity trees, and large down woody material. Habitat requirements of these species can best be met through retention and management of riparian zones or patches of upland hardwoods interspersed within plantations.

Keywords: Harvesting, thinnning, even-aged silviculture, habitat, wildlife

INTRODUCTION

Pine silvicultural practices in the South vary widely within and among ownership classes. Private non-industrial forest landowners, who control about 73% of the South's commercial forests, generally employ minimum forest

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[1] In cooperation with School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas 75962

management and typically rely on natural regeneration following some type of selective timber harvesting. On National Forests of the South, which comprise almost 6% of the South's commercial forest acreage, even-aged management (on about a 65-year rotation) employing clearcutting, site preparation, and planting has dominated pine silvicultural practices for about the last 25 years. Industrial forest lands comprise almost 25% (about 17 million hectares) of the South's commercial forests, and about 31% of this acreage (5.4 million hectares) is in plantations (USDA Forest Service 1988). It is on these lands where pine silviculture is practiced most intensively. Management typically involves clearcutting, intensive site preparation, planting of genetically improved pine seedlings, and short (25- to 35-year) rotations for fiber production. Subsequent treatments may include herbicide and fertilizer applications, prescribed burning, and one or more thinning operations. All of these practices influence wildlife abundance and diversity.

Most industrial forest acreage is now or soon will be leased for hunting access rights. Growing revenues derived from hunting leases, together with improved public relations benefits garnered from integrated timber and wildlife management programs, has increased forest industry interest in wildlife management (Halls 1975). Many of the larger companies now employ professional wildlife biologists. Except for threatened and endangered species, corporate concerns for nongame species are generally incidental and secondary compared to game species (Melchiors 1983). Principal game species on industry lands include white-tailed deer (*Odocoileus virginianus*), bobwhite quail (*Colinus virginianus*), and eastern wild turkey (*Meleagris gallopavo*).

This paper summarizes information on how intensive management affects wildlife in southern pine plantations. It offers approaches for maximizing habitat quality at minimum expense to classical planation management procedures. Although management for both game and nongame wildlife are addressed, the literature on game species is far more extensive. Emphasis here is on general principles rather than specific management prescriptions for individual species. Major factors to be discussed include harvesting, site preparation, intermediate stand treatments, riparian zone management, and snags and down wood retention.

HARVESTING

Even-aged management begins with the complete (clearcutting) or partial removal (seed tree and shelterwood cuts) of an existing stand. Factors at this stage of management that most influence wildlife include (a) method of regeneration (b) logging impacts, (c) size, shape, and juxtaposition of cutting units, and (d) rotation length.

Clearcutting alters habitat more dramatically than does any other regeneration method, but relatively little research has been conducted comparing wildlife habitat under clearcutting, seed tree, or shelterwood

systems. Seed trees provide perching sites for birds of prey and flycatchers and foraging habitat for woodpeckers and bark gleaning birds. Consequently, seed tree and shelterwood cuts will provide greater nongame diversity prior to removal of seed trees (Smith 1988). Because they alter microclimate less than does clearcutting, seed tree and shelterwood cuts would be less detrimental to microclimate-sensitive species such as terrestrial salamanders (Ramotnik and Scott 1988).

Logging with heavy equipment under wet conditions can result in soil compaction, erosion, and reduced site productivity. Soil compaction can be detrimental to fossorial small mammals and herpetofauna (Ramotnik and Scott 1988). However, soil depressions created under wet logging conditions could improve habitat for amphibians by creating temporary pools of benefit to larval toads, frogs, and salamanders that require water for maturation.

Wildlife biologists have long stressed the need for increasing both within- and between-stand diversity. Within-stand diversity can be increased by retaining large down woody material, snags (standing dead trees), and seed trees, or burning different portions of a stand at different seasons and/or at different frequencies. Longer intervals between burns within pole stands permit the development of one or more additional vegetation strata, which increases bird diversity and abundance (Noble et al. 1980).

Foresters have generally concentrated on increasing between-stand diversity by scheduling and arranging cutting units to create a mosaic of small, different-aged, irregularly shaped stands. These practices create favorable conditions for many early-succession species like deer, quail, and rabbits. For most game species, cuts should be as small as silviculturally and economically practical. Elongate and irregularly shaped cuts provide greater "edge" and habitat diversity than do square or rectangular cuts (McGinnes 1969). The most effective edge conditions occur where age differences between adjacent stands are maximized. For this reason, new clearcuts should be placed next to mid-rotational stands (Harris 1984). Large clearcuts are aesthetically unpleasing to many people and are of limited value to most game species.

Rotation lengths vary with site quality, management objectives, and pine species. Shorter rotations favor early-succession wildlife because more acreage is in younger stands. However, with shorter rotations, there is insufficient time for hardwoods to produce hard mast (nuts and acorns) on which many game and nongame wildlife depend. Shorter rotations also mean fewer snags and den trees and less down woody material.

As more emphasis is placed on nongame species and conservation of threatened or endangered species, traditional guidelines relative to stand size and shape will have to be altered (Smith 1988). For example, birds that require large contiguous forest stands (i.e., "interior", "area-sensitive" species) are adversely affected by forest fragmentation--often as a result of increased nest parasitism by brown-headed cowbirds (*Molothrus ater*) (Brittingham and Temple 1983). Likewise, square cutting units are less detrimental to interior species than elongate cuts, because the amount of edge habitat is reduced (Smith 1988).

SITE PREPARATION

Because different types and intensities of site preparation produce different plant responses, foresters may find it practical to tailor treatments to benefit selected wildlife species. For example, soft mast (fruits and berries) is a major component in the diets of many game and nongame species, and should be promoted in clearcuts because short rotations preclude hard mast production. However, soft mast availability is reduced as site preparation intensity is increased (Johnson and Landers 1978, Stransky and Roese 1984). Therefore, foresters can benefit wildlife by using the least intensive site preparation practical to meet silvicultural needs.

Soft mast supplies will be low for the first two years following site preparation, will peak within about 4 to 5 years (Johnson and Landers 1978), and may begin to decline as early as 6 years after site preparation as canopy closure commences (Campo and Hurst 1981). Lesser amounts of soft mast will be produced by shade-tolerant species after canopy closures, but production will increase following subsequent thinning operations.

Logging debris and roots are often raked into windrows and burned to increase planting space and to facilitate planting. However, retention of windrows can enhance within-stand diversity by providing additional habitat for rabbits, small mammals, and other nongame species (Maser et al. 1979). Burned or partially burned windrows often produce dense stands of fruit-producing shrubs relished by many wildlife species (Campo and Hurst 1981). However, burning of windrows reduces escape cover and is generally thought to reduce windrow value to species dependent on down woody material (Maser et al. 1979). Thus, at least a portion of the windrows should be left unburned; little planting space would be lost if pine were planted close to and on either side of the windrows. Conserving windrows may not be practical where excessive pine seedling damage from rodents is likely, but a few strategically placed snags or residual trees may increase raptor predations sufficiently to reduce seedling damage to an acceptable level.

PLANTING

Planting considerations that influence wildlife include spacing and the species (or genotype) selected for planting. Faster-growing loblolly (Pinus taeda) and slash pines (P. elliottii) have generally been favored in recent years over shortleaf (P. echinata) and longleaf pine (P. palustrus). Planting faster-growing species or improved genetic strains means quicker canopy closure and faster reductions in understory forage. Faster-growing trees may harbor fewer arthropods for bark gleaning birds (Dickson 1982). However, with faster growing trees, rotations can be shortened, and more habitat can be made available for early-succession wildlife species. Wider pine spacing benefits wildlife through increased forage production that persists longer because of delayed canopy closure.

INTERMEDIATE STAND TREATMENTS

After canopy closure, dense pine plantations furnish little for wildlife other than escape or thermal cover. To improve wildlife habitat, intermediate treatments like thinning and burning should be employed as early and often as economically feasible. Other treatments, such as fertilizer and herbicide applications, also influence habitat conditions in both positive and negative ways.

Frequent thinning enhances understory forage production (Blair 1960), forage quality (Halls and Epps 1969), and soft mast production (Halls and Alcaniz 1968). However, on certain sites, excessive thinning without burning may result in a dense hardwood midstory that reduces understory forage through shading and competition (Blair and Enghardt 1976). Thinning also facilitates other understory treatments such as plantings of key forage species (Halls 1973).

Prescribed burning, one of the most valuable tools of southern resource managers, is used for site preparation, fire hazard reduction, hardwood control, control of brown-spot needle disease (Scirrhia acicola) in longleaf pine, and for improving livestock forage conditions. Furthermore, burning at the right season and frequency is generally considered beneficial to game species (Landers 1987), amphibians and reptiles (Means and Campbell 1981), and early-succession small mammals and their predators (Landers 1987).

Because structurally complex communities support greater nongame bird diversity and abundance, fire can drastically alter avian communities. Birds and mammals that are dependent on hardwood communities are adversely affected by fires that destroy hardwoods and eliminate snags (Conner 1981). Burning can also result in long-term reductions in soft mast production on some sites (Lay 1956). In general, burning should be employed on upland sites in a dispersed pattern on a rotational basis.

Greatest pine responses to fertilization have occurred when phosphorus is applied at planting time on Coastal Plain sites and when nitrogen is applied to pole-size stands on both Coastal Plain and Piedmont sites (Wells and Crutchfield 1974). Few studies have evaluated effects of pine fertilization on wildlife. On nutrient-deficient soils, fertilization should increase understory production and improve forage quality, but some legumes may be adversely affected (Buckner and Landers 1980, Campo and Hurst 1981). Benefits may also be offset by accelerated canopy closure and shorter rotations.

Herbicides play an integral part in plantation establishment and management. Available data suggest that herbicide effects on habitat are generally short-term and that acute toxicity problems are generally unlikely (McComb and Hurst 1987); however, long-term consequences of repeated applications on floral and faunal diversity are unknown. Growing public sentiment against the use of pesticides in general will likely affect future availability of forest herbicides. Public support could be increased if foresters conducted or supported more research on environmental effects of herbicides, encouraged the development and use of more selective

herbicides (e.g., those less damaging to key soft mast producers), and minimized the amount of area treated by using spot or banded applications.

RIPARIAN ZONES

To minimize non-point source pollution and to enhance wildlife habitat, the U.S.D.A. Forest Service and several large industrial forest companies now retain forest stands along intermittent and permanent streams when adjacent stands are converted to pine plantations. These remnant stands (variously referred to as riparian zones, filter strips, stringers, streamers, or streamside management zones) vary widely in width and habitat quality. Where soils, topography, and weather permit, the larger pines and more valuable hardwoods are often harvested from these zones, thereby diminishing their value for wildlife. As management intensifies in the adjacent plantations, riparian zones will become critical sources of hard mast, snags, den trees, and large down woody material.

The value of riparian zones to most wildlife remains largely undefined, but research is now underway to assess how riparian zones of different widths influence abundance and diversity of an array of game and nongame species (Dickson and Huntley 1987, Dickson and Williamson 1988). Riparian zones obviously add habitat diversity and substantial edge, and may serve as travel corridors and permit genetic interchange between otherwise isolated animal populations. Travel corridors that connect forest fragments may also enhance avian diversity (MacClintock et al. 1977) and facilitate repopulation of disturbed sites (Smith 1988).

Optimum widths for riparian zones will vary for each species. For example, gray (Sciurus carolinensis) and fox (S. niger) squirrels in east Texas were abundant in riparian zones wider than 50 m but were virtually absent from zones less than 40 m wide (Dickson and Williamson 1988).

Although riparian zones occupy considerable acreage, little forest management has been practiced in them to date. Recent increase in demand for hardwoods has heightened interest in growing quality hardwoods in riparian zones. If integrated with wildlife needs, hardwood management could benefit wildlife while increasing revenues over that obtained from timber alone (McKee 1987). For example, selection for and management of preferred mast producers and deadening of nonpreferred hardwoods could benefit many game and nongame species through increased availability of mast, snags, and down woody material.

SNAGS AND DOWN WOOD

Snags are an important habitat component, providing roosting, nesting, perching, and foraging sites for many wildlife species. Primary cavity

nesting birds (those that can excavate their own cavities) and secondary cavity nesters (those that use natural or otherwise created cavities) comprise a large component of the forest avifauna and play a significant role in regulating endemic insect populations. Tree cavities are also important to many mammals such as squirrels (Sciurus spp. and Tamiasciurus spp.), wood rats (Neotoma spp.), raccoons (Procyon lotor), and opossum (Didelphis virginiana). Thus, forestry practices that reduce decaying older trees and snags adversely affect many wildlife species and may indirectly affect forest insect populations.

Whereas snags smaller than 25 cm in diameter may be used for foraging, many cavity-nesting birds prefer snags larger than 38 cm (Evans and Conner 1979, Neitro et al. 1985). Snags can be created by deadening large hardwoods by herbicide injection or girdling (Conner et al. 1983). Suitable cavity trees can also be created by inoculation of trees with appropriate fungi (Conner and Locke 1983). But retaining adequate densities of large enough hardwood trees within pine plantations may not be practical under increasingly shorter rotations. Snag retention within clearcuts will increase bird diversity and abundance (Dickson et al. 1983), but may increase nest parasitism by cowbirds (Smith 1988). When seed tree or shelterwood cuts are made, a portion of the seed trees could be retained and managed for snags. Alternatively, snag and cavity requirements could be met within riparian zones or patches of upland hardwoods.

Dead and down woody material (stumps, roots, bark, limbs, and logs) serve many important biological functions including soil protection and nutrient cycling. These materials, especially the larger components, also create habitat structure and diversity that is of great importance to many terrestrial and aquatic wildlife species (Maser et al. 1979, Seehorn 1987). These materials are abundant in natural unmanaged stands but will decrease in abundance as management intensifies and rotations are shortened. Where large down woody material is present, prescribed burning can be used to meet silvicultural and other objectives without a major loss in large down woody materials if fuel moisture content, weather, and burning techniques are carefully considered (Maser et al. 1979).

CONCLUSIONS

Our knowledge of forest-wildlife interactions is far from complete, but enough is known to benefit many wildlife species through modification of current forestry practices. As forest management intensifies, it will be increasingly difficult to accomodate the needs of many wildlife species. Those species that benefit from early successional stages will fare well with even limited forestry concessions. Managing for those species dependent on hardwoods, cavity trees, snags, and large down woody material will require greater concessions.

To a large extent, relative to their counterparts in the western United States, forest industries of the South have been little affected by

environmental pressures. As populations, education, and wealth increase across the South, this situation will change. To avoid future environmental confrontations, foresters should heed Ellis's (1987) suggestion that the best approach is "to demonstrate a strong concern for the environment, to seek effective ties with other natural resource professionals and environmental organizations, and to marshal good information on the influences of timber management on wildlife, fish, and other resources." Companies that embrace this philosophy and effectively manage and market their nontimber resources stand to gain financially and from improved public relations.

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S Y L V I C U L T U R E   C L O N A L E
D E S   E U C A L Y P T U S   A U   C O N G O

Philippe VIGNERON et Jean-Claude DELWAULLE

Chercheur et Directeur
Centre Technique Forestier Tropical
Pointe-Noire, Congo

FDC: 238: 176.1 Eucalyptus spp.: 232.1: (672.4)

SUMMARY

The present paper reviews research work undertaken by the Centre Technique Forestier Tropical in Congo for implementation in large scale Eucalyptus hybrid clonal plantations by the National Afforestation Company (UAIC). Main studies concern fertilization, spacing and coppice management in order to improve the yield of the plantations.

After a brief reminder of the interest of clonal selections and clonal plantations, the authors review the trials and their results. They, in particular, discuss specificities of silvicultural research for clonal plantations : some trials can be established more easily but generalization is more critical mainly because of clonal variation in response to treatments.

INTRODUCTION

Voici maintenant plus de 11 ans qu'ont été mises en place les premières plantations clonales d'Eucalyptus au Congo. Cette réussite spectaculaire a considérablement fait évoluer l'aspect des plantations d'Eucalyptus en zone tropicale et subtropicale tant l'option clonale s'est généralisée. Ce type de sylviculture, appliqué à des essences à courte révolution, présente d'indéniables avantages. Les populations de base, qu'elles soient directement issues de l'aire naturelle ou qu'elles proviennent de peuplements semenciers artificiels sont très hétérogènes. Pour les Eucalyptus, dont la reproduction est préférentiellement allogame comme l'ont montré divers travaux résumés par Moran et Bell (1983) et, qui présentent pour les principales espèces une forte variabilité génétique intrapopulation, cette hétérogénéité est bien connue. Elle est d'ailleurs souvent soulignée par la présence d'une proportion non négligeable d'individus présentant une dépression consanguine. L'utilisation de vergers à graines de clones sélectionnés améliore quelque peu la situation mais les peuplements obtenus sont loin d'être réguliers. Les travaux d'amélioration génétique ne

sont pas encore assez anciens pour déboucher sur des populations satisfaisantes et la voie la plus immédiate pour améliorer la production et l'homogénéité est d'isoler le ou les génotypes(s) les meilleurs pour les caractères considérés puis de les multiplier végétativement à l'infini. Bien que l'idéal soit de manipuler un petit nombre de clones - à la limite un seul comme cela est souvent le cas pour l'hévéa ou la banane -les génotypes actuels ne sont pas suffisamment éprouvés pour que l'on puisse agir ainsi. Le forestier, pour ne pas courir à la faillite se voit donc contraint d'utiliser un grand nombre de clones et de les renouveler dans le temps et dans l'espace. Cette contrainte pèse lourdement sur tout le processus : gestion des parcs multiplicatifs, récolte des rejets, conduite à la pépinière ...

Pour le chercheur, cela est un progrès qui peut paraître considérable, le bouturage permet la réalisation d'essais sylvicoles très contrôlés dans lesquels il est possible de s'affranchir totalement des variations dues au génotype. La puissance des dispositifs s'en trouve améliorée mais, paradoxalement, les résultats obtenus peuvent devenir difficilement généralisables en raison de l'existence d'interactions génotype x environnement.

Après avoir exposé les principaux résultats obtenus au Centre Technique Forestier Tropical (CTFT) en matière de sylviculture, nous essayerons de dégager les problèmes liés aux caractères clonaux et envisagerons des solutions possibles.

HISTORIQUE DE LA SITUATION

La génèse des plantations clonales d'Eucalyptus au Congo a été déjà largement exposée (Delwaulle *et als* 1980, Delwaulle 1980, Vigneron 1988). Le bouturage herbacé mis au point au Congo entre 1969 et 1973 (Martin et Quillet 1974) puis développé du point de vue recherche avec la réalisation des premiers tests clonaux entre 1975 et 1977 (Chaperon et Quillet 1977) a débouché en 1978 sur la mise en place de vastes plantations clonales (Corbasson 1986, Delwaulle 1988) couvrant actuellement 30 000 ha dans les savanes côtières congolaises.

La région, 4°45' de latitude Sud, est constituée de plateaux de faible altitude (80 m environ) au relief généralement mou. Bien que proche de l'Equateur, le climat est de type tropical Austral avec deux saisons bien caractérisées. Une saison chaude et pluvieuse de novembre à mai, avec envrion 1 250 mm de précipitations et une saison plus fraîche, sans pluie mais très nuageuse et à hygrométrie toujours élevée, de fin mai à fin octobre. Les sols sont sableux, profonds mais très pauvres en éléments minéraux, notamment en potasse et en matière organique. Ils supportent un maigre tapis graminéen et quelques rares arbustes. En raison de leur pauvreté, ces sols ne peuvent faire l'objet d'aucune utilisation agricole ou pastorale, même extensive. Par contre, la Recherche a montré les perspectives remarquables qu'offrent, sur ce site, les Eucalyptus en matière de valorisation forestière.

EXPERIMENTATION

Le passage de populations issues de semis, très hétérogènes et peu productives (10 à 12 m^3/ha/an) à des peuplements clonaux homogènes et productifs (30 m^3/ha/an en test clonal pour les meilleurs clones) nous a contraint à reprendre une bonne partie de l'expérimentation déjà réalisée en matière de techniques sylvicoles. On était en effet en droit de penser qu'un matériel végétal potentiellement plus performant pourrait mieux profiter des apports d'engrais et nécessiterait des densités de plantation plus faibles pour pouvoir exprimer ces potentialités. Le travail du sol et les techniques de plantation ne semblaient pas devoir, dans un premier temps, être fondamentalement changées bien que les problèmes d'organisation aient rendu certains aménagements impératifs (mécanisation du piquetage, étalement de la période de plantation, espacement des lignes de plantation en fonction de la largeur de travail des engins d'entretien). Les principaux essais ont donc eu pour thème la fertilisation et la densité de plantation. Ce n'est qu'en 1986, suite au passage de l'exploitation au stade industriel qu'ont pu être abordés les problèmes de gestion du taillis.

F e r t i l i s a t i o n

Depuis 1976, dix sept essais ont été mis en place. Ils concernent les doses et modes d'apports de KCl et NPK à la plantation, l'équilibre d'un engrais complet NPK, l'effet des oligoélements et de la fertilisation organique, enfin les apports en cours de rotation et la fertilisation du taillis (dose et date d'apport de KCl, dose de NPK, factoriel NPK) (Vigneron 1987, Chauvière et Vigneron 1987). Les dispositifs utilisés sont en blocs complets. Le tableau en annexe donne les caractéristiques principales des essais. Les essais sont mis en place après un travail du sol le plus homogène possible au moyen d'un pulvériseur lourd travaillant sur 3 m de largeur à 15 cm de profondeur ; le choix de clones testeurs a été dicté soit par des impératifs pratiques (disponibilité en boutures homogènes et bienvenantes) soit par leur excellent taux de reprise (supérieur à 99%) et leur bonne croissance. Les entretiens sont particulièrement soignés afin de réduire au maximum les effets d'interaction traitement x milieu (recrû plus important dans les traitements avec azote). Les mensurations sont faites habituellement à 6 ou 12 mois (hauteur totale seulement) puis à 2, 3, 4 et 7 ans (hauteur et circonférence à 1,3 m). Différentes analyses sont effectuées : analyses de variance sur les effets traitements, effets principaux, interactions entre éléments, modélisation des effets doses ou des effets d'équilibre par régression, décomposition annuelle des effets par analyse de covariance pour la recherche des dates optimales d'apports, etc..

De nombreux problèmes se trouvent posés dont nous débattrons plus loin. D'intéressants résultats ont déjà été acquis ou confirmés :

Premier apport à la plantation.

Effets principaux : le phosphore, amené sous forme de superphosphate ne s'est jamais montré efficace quelle que soit la dose utilisée. Le potassium, sous forme de KCl ou K_2SO_4, marque souvent assez peu la première année mais, apporté en masse, il a un effet moyen, positif, significatif

sur la croissance en volume dès la deuxième année. La dose optimale semble se situer vers 150 kg/ha de KCl épandu en plein, procurant un gain d'environ 25 % sur le volume, au moins pour les meilleurs clones. L'effet de l'azote, amené généralement sous forme d 'ammonitrate, est extrêmement net dès les premiers mois (gain de 40 % sur la hauteur à 9 mois) ; à 3 ans, on observe jusqu'à 40 % de gain sur le volume total avec un apport localisé d'environ 80 g d'ammonitrate par plant ; cet effet s'atténue très notablement entre 3 et 4 ans, le gain réalisé les premières années s'amenuisant et pouvant même disparaître.

Interactions : dans tous les cas, le mélange NPK donne les meilleurs résultats sans que l'on puisse pourtant mettre en évidence une notable interaction entre éléments, seule a été quelquefois décelée une faible interaction P x K. L'engrais complet NPK a un effet non seulement plus fort que ceux de N ou NK mais aussi plus prolongé. Il semble donc que le potassium et l'association potassium/phosphore viennent soutenir l'effet starter de l'azote.

Les apports d'oligoélements et de matière organique ont donné peu de résultats, seul le zinc amène un léger gain sur la croissance en hauteur en première année, mais cet effet s'estompe.

Apport en cours de rotation :

Les résultats sont très semblables à ceux obtenus en premier apport. Les effets principaux et les interactions sont les mêmes à savoir un faible effet de KCl l'année suivant son apport, pas d'effet de phosphate mais un très net effet positif de l'azote. L'essai factoriel, conduit sur six clones différents, a montré qu'un gain moyen de 11 % sur le volume à 4 ans était obtenu par l'apport à 2 ans de 150 g d'ammonitrate, 33 % par plant. Cet effet, d'abord visible, sur la circonférence puis sur la hauteur, semble lui aussi s'atténuer avec le temps. On envisage donc d'étudier la pertinance économique d'un dernier apport d'engrais un ou deux ans avant l'exploitation, cette dernière se faisant vers 6 ou 7 ans.

Des recherches en matière de fertilisation sont à poursuivre avec notamment l'étude de l'effet retard du KCl apporté en masse à la plantation, l'optimisation de l'apport à 2 ans et d'un éventuel 3ème apport. Les résultats obtenus ces dernières années permettent cependant une nette amélioration de la production : le cumul des effets en première et deuxième apport assure d'ores et déjà un gain à 4 ans de l'ordre de 60 % par rapport aux témoins sans engrais et de 25 à 30 % par rapport aux anciennes pratiques.

D e n s i t é   d e   p l a n t a t i o n

Du fait du clonage, le matériel végétal est génétiquement parfaitement homogène et, grâce à la sélection, d'excellente conformation. L'objectif étant de pratiquer une exploitation vers 6 ou 7 ans pour la fourniture de bois de trituration et éventuellement de poteaux de ligne, la plantation doit être réalisée à écartement définitif. Les densités préconisées pour les plantations préindustrielles réalisées avec *Eucalyptus tereticornis* (variété locale 12 ABL originaire de Madagascar) étaient d'environ 950 tiges/ha, assurant ainsi une fermeture au moins partielle du couvert suffi-

samment rapide pour contrôler efficacement le recrû herbacé (Groulez 1967). Dès les premiers succès de multiplication végétative, la mise en place des essais a été faite en utilisant des densités plus faibles jusqu'à une centaine de tiges/ha, tant était grande la confiance placée dans ces individus supérieurs. Les volumes unitaires susceptibles d'être atteints paraissaient sans commune mesure avec ceux obtenus en plantations issues de semis, les génotypes sélectionnnés tirant bien mieux parti de l'espace vital qui leur était dévolu. Afin de préciser la fourchette de densité assurant la production optimale de ce nouveau matériel végétal, 4 essais en blocs monoclonaux ont été successivement mis en place. Les caractéristiques principales sont données dans le tableau ci-dessous :

Essais	77.14	78.13	79.10	81.29
Date de mise en place	Novembre 1977	Novembre 1978	Décembre 1979	Novembre 1981
Clones	1.41 et 2.29	1.45 et 2.60	2.3 et 2.6	1.45
Dispositif	Blocs	Marynen	Nelder	Marynen
Densités testées	278 à 10 000 à l'hectare	278 à 816	232 à 816	276 à 1 600

Les densités testées se répartissent entre 232 et 10 000 tiges/ha, l'essentiel des traitements explorant la fourchette 300 à 1 000 individus à l'ha. Six clones servent de testeurs. La très bonne reprise du matériel, supérieure à 99 %, et son homogénéïté génétique nous ont poussé à développer des dispositifs extrêmement compacts, puissants et robustes. Le dispositif de Marynen (1963) a été utilisé dans deux tests et a donné du point de vue du biométricien d'excellents résultats. Le dispositif de Nelder s'est par contre révélé fragile à l'excès et incapable de fournir des renseignements solides (très grande sensibilité à la perte d'une information, mauvaise répartition spatiale des traitements). Les essais ont été mesurés annuellement au moins pendant sept ans (hauteur et circonférence à 1,3 m). L'estimation des volumes individuels a été effectuée à l'aide d'un tarif à deux entrées.

Les meilleures croissances en hauteur s'observent pour les plus faibles densités, c'est-à-dire, là où la compétition entre individus est la moins forte. Cet effet, très significatif dès le deuxième année, s'accentue au fur et à mesure du vieillissement du peuplement. Il est quasiment linéaire en fonction de la densité de la plantation, la hauteur perdant à 5 ou 6 ans environ 0,7 m pour 100 individus supplémentaires à l'hectare. Cela traduit d'une part, le déséquilibre du peuplement et d'autre part, la très faible fertilité du milieu jouant comme facteur limitant de la croissance en hauteur, bloquant même complètement celle-ci vers 4 ans pour des densités supérieures à 2 000 tiges/ha.

La croissance individuelle en volume se trouve toujours favorisée par

une moindre concurrence entre arbres. Il est donc logique de constater que c'est aux faibles densités que l'on enregistre les plus gros individus. La pauvreté des sols et leur mauvaise capacité de rétention en eau sont à l'origine d'une forte concurrence dès le premier âge. A un an, on observe une augmentation régulière et significative de la circonférence en passant des écartements 3,5 m x 3,5 m à 6 m x 6 m. Dès deux ans, la différence de croissance entre des densités aussi faibles que 330 et 270 tiges/ha est significative.

En fin de révolution, vers 6 ou 7 ans, la densité de plantation qui optimise la production à l'hectare se situe aux environs de 650 à 750 tiges à l'ha, une perte de production relativement importante étant observée de part et d'autre de ces limites. Cette densité est notablement inférieure à celle antérieurement préconisée. Le volume commercial de bois fort optimal est obtenu avec des densités légèrement inférieures, vraisemblablement entre 600 et 700 tiges/ha. La définition exacte de l'optimum économique de densité dépend cependant d'un très grand nombre de paramètres : prix du plant, coût des entretiens, loyer de l'argent investi, coût de l'abattage, de l'écorçage et de la manutention (vraisemblablement très déterminants), diamètre fin bout minimum accepté par le client, etc... Elle devient alors du ressort de l'industriel et de l'économiste. C'est ainsi que les plantations actuelles de l'Unité d'Afforestation Industrielle du Congo (UAIC) sont réalisées avec 532 tiges/ha.

Gestion du taillis

Le passage au stade industriel de l'exploitation s'est fait en 1986-1987, soit 8 ans après la mise en place des premières parcelles clonales par l'UAIC. La production atteint actuellement environ 500 000 tonnes de rondins écorcés par an. Après l'exploitation, l'objectif est de reconstituer, à partir des rejets, un peuplement de tailllis aussi productif que possible en concentrant cette production de matière ligneuse dans un nombre restreint de tiges de volume individuel suffisant. Plus le nombre de brins conservés est grand, plus le volume moyen des brins est faible et plus le volume total est fort. L'observation du taillis laissé sans intervention particulière montre que les clones actuels présentent une moyenne de 5 à 7 brins par souche. Dès 24 mois la souche ne nourrit en fait que 2 ou 3 de ces brins, le plus gros accapare 50 % de l'accroissement et les deux plus gros ne laissant qu'un très faible reliquat aux 3 ou 4 autres petits brins, leur permettant juste de ne pas disparaître. Ces petits brins ont cependant atteint des diamètres non négligeables et ont donc mobilisé une partie des potentialités nutritives de la souche. Comment, dès lors réorienter ces flux trophiques non valorisés vers les plus beaux brins ? Quand effectuer le dépressage, combien de brins conserver et lesquels ? L'étude précise du comportement des espèces (corrélations entre variables mesurées sur les différents brins) a permis de d'envisager un certain nombre d'interventions possibles et les thèmes abordés dans les divers essais concernés : citons l'intensité du dépressage, la date du dépressage, le contrôle de nouveaux rejets par buttage de la souche, la fertilisation et l'effet de l'écartement initial (Vigneron, 1989). Les principales caractéristiques des essais réalisés sont données dans le tableau ci-après :

<table>
<tr><td colspan="2">Essai n°</td><td>R 86.1</td><td>R 87.1</td><td>R 87.3</td><td>78.13</td><td>R 87.2</td></tr>
<tr><td rowspan="3">Trai-
te-
ment</td><td>dépressage</td><td colspan="3">on conserve 1,2 ou tous les brins</td><td rowspan="3">densité de plantation 278 à

tiges/ha sans dépressage</td><td rowspan="3">1 brin avec buttage doses KCl

et NPK</td></tr>
<tr><td>date</td><td>à 9,15-22 mois après la coupe</td><td>10,15 mois</td><td>11 mois</td></tr>
<tr><td>buttage</td><td>sans</td><td colspan="2">avec ou sans</td></tr>
<tr><td colspan="2">dispositif
date de coupe</td><td>3 RC
01.1986</td><td>6 RC
08.1986</td><td>6 RC
08.1986</td><td>Marynen
06.1986</td><td>4 RC
8.1986</td></tr>
<tr><td colspan="2">Matériel végétal</td><td colspan="2"><u>E. tereticornis x grandis</u>
mélange multiclonal</td><td>E. PF 1
mélange
multiclonal</td><td>clone 1.45</td><td>E. PF 1
mélange
multiclonal</td></tr>
</table>

Sauf pour l'essai 78.13, le matériel végétal est constitué par des mélanges pied à pied multiclonaux. De ce fait nous avons multiplié le nombre d'individus mesurés par placeau unitaire (essai R 87.2) ou multiplié le nombre de répétitions (essais R.87.1 et R 87.3) selon les contraintes imposées par le type de traitement et la parcelle d'origine. Les variables mesurées sont la hauteur dominante de la cépée (en général celle du plus gros brin) et la circonférence à 1,3 m des 1,2 ou 3 plus gros brins. Dans tous les cas la covariable permettant le contrôle de l'état initial du peuplement est la valeur prise par la variable considérée au moment de l'intervention. Ces essais, entretenus et mesurés régulièrement, permettent déjà de bien cerner le problème de la sylviculture des taillis clonaux d'Eucalyptus dans la région de Pointe-Noire.

La suppression d'un certain nombre de brins entraîne une augmentation significative de la croissance du ou des brin(s) conservé(s). Il existe donc des compétitions interbrins qui sont en partie levées par le dépressage, la perte des brins les plus petits n'étant cependant pas totalement compensée. La hauteur dominante de la souche n'est pas affectée mais la surface terrière individuelle des brins est d'autant plus forte qu'ils sont moins nombreux, le gain atteignant environ 35 % avant l'âge de 3 ans. La date d'intervention du dépressage ne paraît avoir aucun effet sur la production : aucune différence significative n'a pu être mise en évidence entre 9 et 22 mois, mais il semble qu'un dépressage plus tardif soit préjudiciable. Pour faciliter l'opération, il est préférable d'intervenir dès que la distinction entre brins est acquise et leur attache solide (pour éviter les chablis), soit pratiquement vers 9 mois. Par ailleurs, la repousse de nouveaux rejets peut être notablement réduite en recouvrant la souche d'une dizaine de centimètres de terre.

Les dispositifs en place concernant l'influence de la densité d'ensouchement sur la production de la première rotation de taillis sont encore trop récents pour que l'on puisse définir la plage de densité optimale. Cependant, dans l'essai Marynen 78.13, on constate que la densité d'ensou-

chement a le même effet sur la croissance, qu'il s'agisse du peuplement initial ou des rejets. Il est vraisemblable qu'elle sera identique pour les deux types de peuplement.

L'épandage de 250 à 350 kg/ha de NPK 13.13.21 permet d'obtenir, un an après, un gain d'environ 15 % sur le volume du brin conservé. Aucun effet immédiat de l'apport de KCl, même à forte dose (400 kg/ha) n'est décelable pour l'instant. Le KCl pourrait cependant jouer un rôle dans le maintien à long terme de la fertilité mais la mise en place de l'essai est encore trop récente pour le démontrer ou l'infirmer.

Il reste certes, beaucoup à faire, mais les premières règles générales de conduite du taillis peuvent être considérées comme acquises : dépressage à 9 mois ne conservant que le plus gros brin sans défaut majeur, buttage des souches ou suppression régulièrement des repousses pendant un ou deux ans,fertilisation de départ avec 250 à 300 kg/ha de NPK 13.13.21. On évalue le coût des opérations sylvicoles, fertilisations successives comprises, à réaliser sur le taillis jusqu'à son exploitation, n'excèdera pas le tiers de l'argent investi pour la première rotation. Le volume total et la valeur marchande du produit que l'on peut espérer bien qu'encore mal connus, paraissent suffisants pour éviter d'envisager une replantation.

DISCUSSION GENERALE

Comme nous l'avions indiqué dans l'introduction, l'industriel, planteur d'Eucalyptus, se voit contraint d'utiliser un nombre conséquent de clones. Ce qui s'explique par au moins quatre bonnes raisons :

. Difficulté et délais nécessaires pour confirmer la valeur en production industrielle du ou des quelques meilleurs génotypes parmi les centaines de candidats sélectionnés sur leurs performances en tests clonaux, malgré l'effort investi dans les tests clonaux.

. Méconnaissance des intéractions génotype x année dans des zones à climat souvent capricieux et risque de voir s'effondrer la production d'un clone suite à un accident climatique quelconque.

. Méconnaissance des niveaux de sensibilité ou de résistance à des maladies fongiques ou virales et à des attaques d'insectes en l'absence de l'agresseur.

. Nécessité d'obtenir un produit pas trop spécifique, capable de s'adapter aux variations du marché international sans risquer d'être déprécié par une particularité jusqu'alors sans importance.

Cette contrainte oblige à un important travail de gestion : identification des souches dans les parcs multiplicatifs, planification du recépage en fonction du temps que met un clone à produire des rejets bouturables, soins particuliers à apporter à chaque clone lors de la phase de bouturage puis d'élevage des plants en pépinière.

Concernant la plantation elle-même, la décision initiale prise au Congo a été de réaliser des parcelles monoclonales afin d'obtenir la plus grande homogénéité possible dans les peuplements, de faciliter l'ensemble des interventions ultérieures, de préserver l'identité de chaque clone et donc éventuellement une utilisation particulière de celui-ci. Cette option est conservée jusqu'à présent avec quelques aménagements concernant la taille et la forme des parcelles. Elle facilite énormément le travail en pépinière en évitant d'avoir à réaliser un mélange de clones (dont on sait qu'il est illusoire d'espérer le réaliser au stade des parcs multiplicatifs) ainsi que les opérations de surveillance phytosanitaire.

L'amélioration de la productivité que pourrait amener un mélange pied à pied de plusieurs clones a fait l'objet de quelques études. Deux essais mis en place en 1979 et 1980 comparent les performances d'une dizaine de clones en situation monoclonale ou mélange multiclonal (Bergonzini, 1985). Les résultats n'ont rien de bien original pour qui a la pratique des dispositifs d'étude monoarbres : l'apparition très rapide de la concurrence, comme nous l'avons montré dans les essais écartements, favorise très nettement les clones à forte croissance initiale et a tendance à bloquer les autres ;en parcelle multiclonale, on assiste donc à un bouleversement du classement des clones mais aussi pour certains, à un changement de forme : grande et fine devenant petite et trapue ou inversement. La structure du peuplement est donc très différente de ce qu'on peut attendre de la simple juxtaposition des individus en raison des compétitions entre clones. Du point de vue de la production totale, le gain supplémentaire obtenu en plantation multiclonale est bien faible, environ 1 m^3/ha et par an à 5 ans, ce qui ne compense pas la plus grande hétérogénéité des peuplements et donc des produits. L'utilisation de placeaux multiclonaux semble à proscrire dans la mesure ou leur structure dépend de l'association de clones considérés et l'option monoclonale pour les plantations industrielles est donc à conserver.

L'ensemble des expérimentations sylvicoles a été réalisé dans le but d'en appliquer les résultats à de grands blocs monoclonaux. Sur la base de ces essais monoclonaux, nous avons pu obtenir des résultats assez précis. A titre d'exemple, Bergonzini (1984) a développé une analyse fine des résultats apportés par un dispositif de Marynen. La valeur obtenue par un placeau élémentaire est décomposée en effets additifs selon ligne et colonne, interaction entre ligne et colonne, effet bloc, interaction ligne x bloc et colonne x bloc et enfin ligne x colonne x bloc. L'ensemble des trois premiers effets (ligne, colonne et ligne x colonne) peut être décomposé afin d'identifier les effets de la surface et de la forme de l'espace vital dévolu à chaque individu. Dans les conditions d'expérimentation du Congo, 9 tiges par placeau suffisent pour obtenir de bonnes estimations.

Les peuplements monoclonaux permettent donc la réalisation des dispositifs particulièrement puissants mais dont les résultats sont vraisemblablement difficilement généralisables. La série d'essais de fertilisation illustre parfaitement ce problème : les résultats les plus fins sont obtenus pour un nombre limité de clones, les résultats les plus généralisables le sont dans les essais où le matériel végétal est le plus diversifié.

De nombreuses observations nous amènent à penser qu'il existe de fortes interactions génotypes x environnement : mauvaise stabilité de certains clones d'une année sur l'autre (interaction génotype x année), discordance des résultats de divers essais engrais (interaction génotype x fertilisation) et écartement (interaction génotype x écartement). Jusqu'à présent, nos essais ont fait l'impasse sur ces interactions et ont tenté de déterminer quels étaient les traitements sylvicoles qui, en moyenne, donnaient les meilleurs résultats. Pour obtenir ces renseignements complémentaires, il apparaît nécessaire, outre de répéter quelques essais particuliers, de traiter en même temps 4 ou 6 clones choisis de manière à représenter au mieux la variabilité génétique disponible.

La réduction du nombre de clones plantés et donc l'augmentation des surfaces occupées par chacun d'eux peut amener à vouloir tirer parti de ces interactions génotype x environnement. En effet, certains clones valorisent très mal les apports d'engrais alors que d'autres seraient susceptibles de tirer profit d'une fertilisation plus soutenue. De même certains génotypes ne peuvent s'exprimer qu'à un faible niveau de concurrence alors que d'autres accepteraient une densité de plantation supérieure à la moyenne. La difficulté réside dans l'évaluation de ces interactions et dans le laps de temps que cela nécessite.

Dans l'idéal, la sensibilité d'un clone à tel ou tel traitement sylvicole devrait être parfaitement connue dès que celui-ci est utilisé en plantation industrielle. Les quelques clones retenus sont issus d'une sélection longue et sévère et il est illusoire de vouloir étudier l'ensemble des candidats. Lors du passage à la phase industrielle, les clones ne sont utilisés pendant quelques années que sur des superficies relativement réduites. Cette première phase permet de confirmer en grandeur le bon comportement au bouturage, en pépinière et bien sûr au champ. Cette période pourrait, en théorie, être mise à profit par l'industriel pour caractériser au mieux la fertilisation optimale de chaque clone. En collaboration avec la Recherche et sur la base des effets moyens mesurés par celle-ci, il est possible de définir une série d'essais systématiquement mis en oeuvre permettant d'ajuster les interventions sylvicoles à chaque clone.

CONCLUSION

La multiplication végétative des meilleurs génotypes permet, à partir de populations encore peu améliorées un gain immédiat et spectaculaire tant du point de vue de la valeur moyenne du peuplement que de son homogénéïté. La mise en oeuvre des techniques de bouturage supposent des investissements assez lourds qui doivent donc être valorisés au mieux par l'industriel. Cette valorisation passe par au moins trois étapes :

. élévation du niveau moyen des populations (amélioration génétique),
. choix méticuleux des génotypes à multiplier (sélection, tests clonaux) ;
. intensification de la sylviculture.

La modification de la structure génétique des plantations nous a amené à revoir un certain nombre de points, en particulier la fertilisation et la densité de plantation. Des progrès considérables ont été enregis-

trés dans ces domaines : abaissement de la densité réduisant le coût d'implantation, fort relèvement de la fertilisation pour un matériel végétal capable d'en tirer profit.

L'apparition d'interactions génotype x environnement, peu sensible au niveau des populations hétérogènes, a fait évoluer les concepts expérimentaux. Les dispositifs qui nous semblent cerner au mieux les effets moyens doivent intégrer 4 à 6 clones productifs mais différents pour un certain nombre de caractères : croissance initiale, aspect du houppier, forme (trapue ou élancée), origine génétique.

Bien qu'actuellement, le nombre de clones présents dans les plantations industrielles soit encore assez grand (plus de 35 à l'UAIC), il semble qu'un nouveau gain de productivité puisse être obtenu en réduisant le nombre de clones utilisés (une dizaine) et en tirant parti des interactions génotype x environnement. Les résultats moyens obtenus par la recherche seraient alors à ajuster presqu'au coup par coup grâce à de petits essais systématiques et un réseau de placeaux permanents.

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PRIMARY FOREST SUCCESSION ON DRIFT SAND: THE ROLE OF THE FOREST FLOOR VEGETATION.

Josef Fanta and Ad F.M. van Hees.

Research Institute for Forestry and Urban Ecology "De Dorschkamp", Wageningen, The Netherlands.

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ABSTRACT

Research on spontaneous processes in forest ecosystems yields indispensable information to present-day forestry. This paper discusses changes in the composition and structure of the forest floor vegetation, the initial organic profile and soil development, and the nutrient turnover during the initial and transient stages of primary succession on dry and poor sandy soils in a still active drift sand area in the Netherlands. The successional sere studied ran from bare ground (drift sand) to 130-year-old forest.

Keywords: primary forest succession, initial organic profile and soil development, nutrient cycling, drift sand, the Netherlands.

INTRODUCTION

Only a few remnants of natural forests are left in Europe, and therefore most of the research on spontaneous processes in forest ecosystems has been carried out in old semi-natural forests. Analysis of these forests yields information on species composition and structure, regeneration dynamics, and interspecific and intraspecific competition under natural circumstances. This information cannot be gathered in man-made forests but is very usefull for their silvicultural treatment.

Research in young, spontaneously develAoped forests can also supply valuable information on spontaneous processes; especially on the intial stages of ecosystem development. The little information available on this aspect is largely contained in descriptive studies. To fill this gap in knowledge, a complex research programme has been developed in the Netherlands. Here, good conditions for the study of initial forest ecosystem development can be found in the drift sand landscapes, that developed in the Middle Ages after the destruction of the primaeval mixed broadleaved forest on poor sandy soils (Koster, 1978). The last remnants of these 'Atlantic deserts' are still active and spontaneous forest succession takes place there.

In this paper we review the preliminary results of the research. We will discuss changes in the composition and structure of the vegetation, the initial organic profile and soil development, and the nutrient turnover during initial and transient stages of the primary forest succession. The successional sere studied covers a period of 130 years; starting on bare ground (drift sand) and ending in old spontaneously deve-

loped Scots pine forest.

VEGETATION DEVELOPMENT

Fanta (1986) and Prach (1989) have studied the spatial and temporal changes in the vegetation of a driftsand landscape in the Netherlands. A generalized scheme of the changes in dominant species is presented in figure 1. Succession starts with the open sand being colonized by Ammophila arenaria, Corynephorus canescens and Festuca rubra; whose habitus enables them to withstand a slow accumulation of sand. Generally they form mono-species patches with a sparse cover. In time the area of Corynephorus canescens extends and the cover increases. New species, such as Polytricum piliferum, Spergula morisonii and lichens will invade this vegetation. At this stage the first successful establishment of Scots pine (Pinus sylvestris) can be observed. This Corynephorus canescens dominated vegetation is replaced by a vegetation in which Festuca ovina spp. ovina and Agrostis vinealis are the dominant species, and mosses (Polytrichum piliferum, Pohlia nutans, Campylopus flexuosus) and several lichens are also present. The increasing size and density of the spontaneously established Scots pine result in the shading and ultimately in the elimination of this pioneer vegetation. Under the closed canopy of the young Scots pine trees (up to 40 years) the forest floor vegetation is very sparse and consists of several Cladonia species, Hypnum cupressiforme and Dicranum scoparium: all with a sparse cover. When the Scots pine is approximately 50 years old a transition into a Deschampsia flexuosa dominated vegetation, with a dense cover, can be observed. When the Scots pine is 80 to 100 years old of the Deschampsia flexuosa starts to decline and Pleurozium schreberi, Vaccinium myrtillus, Vaccinium vitis idaea and Empetrum nigrum will establish. Gradually, both Vaccinium species and Empetrum nigrum expand their cover, forming large patches.

SOIL DEVELOPMENT

Changes in the soil profile under Scots pine stands of different ages on drift sand have been studied (Mettivier Meyer et. al., 1986; Fanta, 1986). The thickness of the organic profile and the differentiation within the organic profile correlates strongly with the age of the stand. Up to ca. 70 years the total thickness of the organic profile increases. In the following period a small decrease can be observed and thereafter the thickness of the organic layer remains more or less constant. With regard to the differentiation in the organic profile the following trends are observed (see figure 2). The thickness of the litter and fermentation horizons increases in the first 50 to 70 years. Thereafter the thickness of the litter horizon remains stable, whereas the thickness of the fermentation horizon decreases slightly. This decrease might be associated with the decreasing cover of the Scots pine stands (opening of the canopy and a lesser input of dead organic matter) and the subsequent formation of a moder-type humus horizon. A humus horizon starts to develop after 50 to 70 years; at first in the form of isolated pockets, later as a continuous layer. The thickness of this horizon increases only slightly in time. In the mineral profile a

distinct E horizon (thickness 2-3 cm.) has been observed in all stands.

There is a marked increase in the BC horizon during succession. Only in the oldest stand a distinct B horizon is present.

Changes in the reserves of soil nutrients (Ca, Mg, K and P) were studied by Sevink and Emmer (in prep). The initial stocks of Ca, Mg, P, and K are very low, because the parent material has a high silicate content and contains little feldspar. The reserves of K in the mineral soil were on average ca. 10 times higher than those of Ca. With the exception of Mg, the contents of all elements in the mineral horizons decreased progressively with the age of the stands. Under these circumstances the organic profile has an important function in the nutrient cycling. P, Ca and Mg clearly accumulate in the organic profile during succession, whereas K reserves in these horizons remain rather constant with increasing age of the forest. The change in the relation K:Ca/Mg during succession is evident and undoubtely has important consequences for the vegetation.

ELEMENT CONTENT AND MATTER TRANSFER BY THE MOSS AND HERB LAYER

The element content and the regulation of matter transfer by the moss and herb layer in this succession sere has been studied in the following stages (Moszynska, in prep.):

I. Scots pine forest, 45 years old, with a sparse vegetation of Deschampsia flexuosa, Dicranum scoparium, Dicranum polyseteum and Hypnum cupressiforme.

II. Scots pine forest, 75 years old, with a vegetation dominated by Deschampsia flexuosa and with Hypnum cupressiforme as the codominant species.

III. Scots pine forest, 120 years old, with a mixed vegetation dominated by Deschampsia flexuosa, Vaccinium myrtillus, Vaccinium vitis idaea and Empetrum nigrum.

The following elements were studied; C,N,P,K,Na,Ca,Mg,Zn.

In all stages forest mosses and Deschampsia flexuosa contained more nitrogen than any other plants (see table 1). Deschampsia flexuosa accumulated high contents of potassium, but Ca, Mg and Mn content was negligible. The amounts of Ca, Mg, and Mn in Vaccinium myrtillus were much higher than those in Deschampsia flexuosa, but the phosphorus content was very low. Compared with Vaccinium myrtillus, much more phosphorus and much less Ca, Mg and Mn were accumulated by Vaccinium vitis idaea and Empetrum nigrum.

For all the elements studied both the amount of elements retained in the living biomass and the amount transferred by dead biomass increases during succession (see table 2.).

The differences between the element contents of summer and autumn leaves of Deschampsia flexuosa, Vaccinium myrtillus and Vaccinium vitis idaea was studied. In general the autumn leaves contained more elements than the summur leaves. After the autumn leaf fall these elements return to the organic profile.

table 1. Element content (% d.wt.) in different plant species.

PLANT SPECIES	ELEMENTS N	P	K	Ca	Mg	Mn
Hypnum cupressiforme	1.880	0.075	0.13	0.13	0.66	0.012
Pleurozium schreberi	2.229	0.095	0.36	0.13	0.82	0.018
Dicranum polysetum	2.142	0.065	0.42	0.11	0.78	0.013
Deschampsia flexuosa	1.930	0.072	1.47	0.01	0.095	0.029
Vaccinium myrtillus	1.609	0.060	0.54	0.74	0.192	0.114
Vaccinium vitis idaea	1.276	0.104	0.74	0.15	0.012	0.053
Empetrum nigrum	1.463	0.120	0.99	0.01	0.059	0.033

table 2. Amount (kg/ha) of matter retained and transferred per element in different successional forest stages.

ELEMENT	SUCCESSIONAL STAGE I	II	III
C transferred	290.6	902.4	1552.0
retained	918.4	1260.0	5170.2
N transferred	13.1	33.2	39.3
retained	33.2	37.0	131.7
P transferred	0.6	1.5	2.4
retained	1.6	1.7	7.2
K transferred	5.2	12.5	12.0
retained	7.3	16.2	28.3
Na transferred	0.1	0.0	0.3
retained	0.3	0.0	0.5
Ca transferred	0.3	2.6	2.6
retained	1.4	1.6	6.2
Mg transferred	0.4	1.4	1.3
retained	0.8	2.0	5.2
Mn transferred	0.2	0.4	0.9
retained	0.6	0.3	2.9
Zn transferred	0.0	0.1	0.2
retained	0.1	0.2	0.5

tabLe 3. Carbon/element ratios for dead biomass in different successional stages.

C/ELEMENT RATIOS	SUCCESSIONAL STAGE I	II	III
C/N	22.2	27.2	39.5
C/P	476.4	605.6	657.6
C/K	56.2	72.3	129.8
C/Na	2641.8	9024.0	6208.0
C/Ca	908.1	347.1	592.4
C/Mg	660.5	635.5	1203.1
C/Mn	1709.4	2050.9	1783.9
C/Zn	7265.0	6941.0	7760.0

The element content of the dead biomass (expressed as a C/element ratio) changes during the succession (see table 3.). The increasing C/N ratio for dead biomass indicates a decreasing rate of decomposition and thus a slower cycling of the minerals within the subsystem formed by the moss/herb layer and the soil. A decrease per unit dead biomass can be observed for the elements N, P, K, Na, Mg. For Ca there is an increase per unit dead biomass during succession. No successional trend is evident for Mn and Zn.

CHANGES IN THE ORGANIC PROFILE AND THEIR INFLUENCE ON THE VEGETATION DEVELOPMENT

Changes in organic profile are associated with the changes in vegetation. The dominance of the grass Deschampsia flexuosa is clearly linked with the formation of the fermentation layer in the organic profile. This stage lasts for some 50 years, in which the dominant Deschampsia flexuosa blocks further vegetation succession. The decay of the Deschampsia synusia coincides with the progressive development of the humus layer. This opens up a niche for the establishment of forest mosses (such as Pleurozium schreberi), low shrubs (Vaccinium myrtillus, Vaccinium vitis idaea and Empetrum nigrum) and other plant species of forests.

Without doubt the changing chemical status of the organic profile during succession is the driving force behind these changes in the vegetation. Potassium is relatively rapidly released from the decomposing dead organic matter. The release of calcium and magnesium starts slowly in the intial stages of succession and accelerates in the later stages. As a result a surplus of potassium arises in the early successional stages and lasts until the Scots pine stand is 80 to 100 years old. This is a favourable situation for Deschampsia flexuosa, which can absorb and accumulate larger amounts of potassium than other plant species (cf. Zimka and Stachurski, 1976). In the stage with dominance of Deschampsia flexuosa (Scots pine 75 years old), the Deschampsia retained 16.2 kg K ha-1, against 1.56 kg Ca ha-1 and 2.0 kg Mg ha-1 (Moszynska, in prep.). In later stages of the succession (Scots pine 120 years old) a very different situation develops. Ca and Mg reserves in the organic profile increase significantly, but amounts of K remain more or less constant. The change in the ratio K:Ca+Mg (the latter two elements prevailing in this relation) indicates different chemical properties of the system, which have consequences for the species composition of the vegetation. The cover of Deschampsia flexuosa decreases and low shrubs and forest mosses establish.

DISCUSSION: THE ROLE OF THE MOSS AND HERB LAYER IN THE ELEMENT TURNOVER

In the young forest ecosystem the largest amount of dead organic material is produced by the Scots pine trees. In these successional seres, Van Berghem et al. (1986) calculated amounts of dead organic matter varying from 2.5 kg m-2 in 30-year-old stands to 10 kg m-2 in 120-year-old stands. During succession the moss and herb layer parti-

cipates in the production of litter on a different scale. In the initial stage of succession little dead organic matter is produced by these layers annually. In later stages the amount increases significantly. Zimka and Stachurski (1976), and Moszynska (1985) even assume that the amount of dead organic matter produced annually by moss and herb layer can equal the amount of litter produced by the Scots pine. Stachurski and Zimka (1975) found important differences in the speed of decomposition: dead organic matter produced by the moss and herb layer decomposes much faster than the litter of Scots pine. These differences in decomposition rates together with the different quality (chemical composition) of the moss/herb and tree litter illustrate the important role of the moss and herb layer in the primary succession. This layer functions as regulators of nutrient turnover, accelerating decomposition and bringing elements into circulation much earlier than the Scots pine trees do. By modifying the chemical properties of the organic profile, the moss and herb layer essentially contributes to the opening of new niches, increasing species diversity and the diversity of ecological relations.

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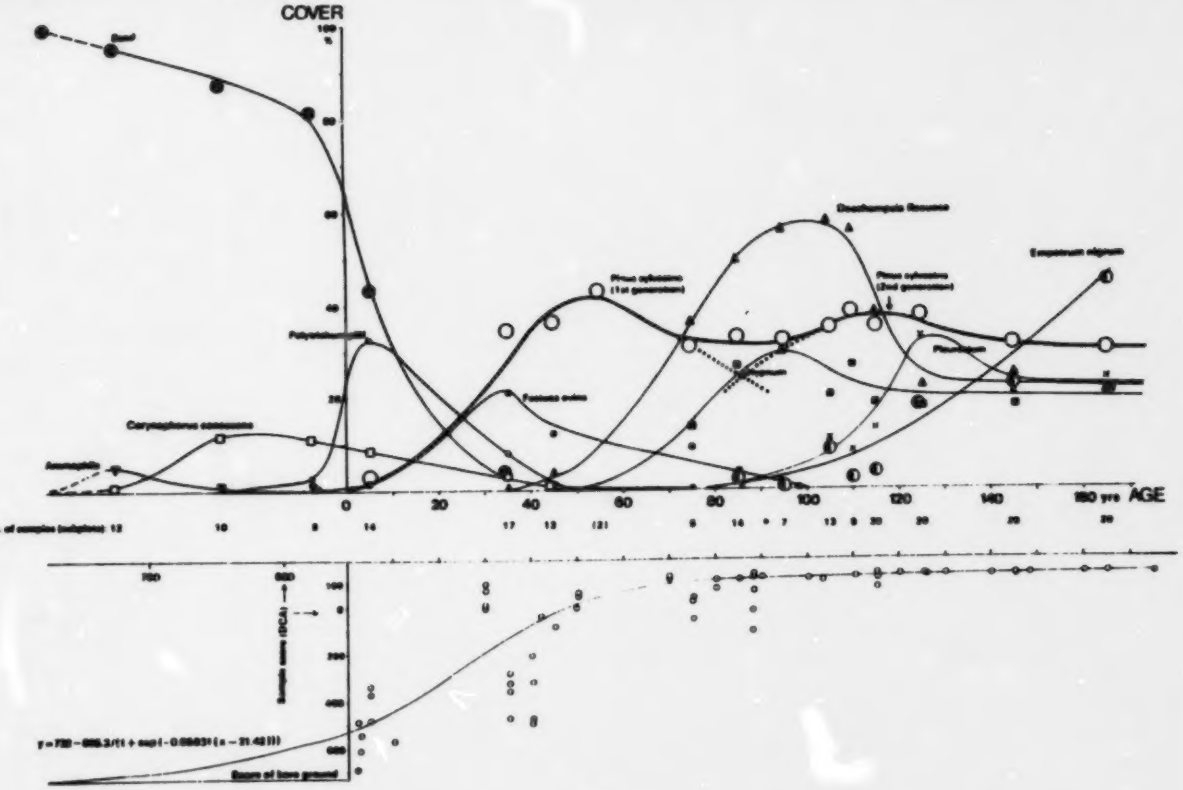

Figure 1 Changes in the dominant species during the succession. Ordination sample scores were used to construct the auxiliary time-scale in the manner that is evident from the plottedregression curve

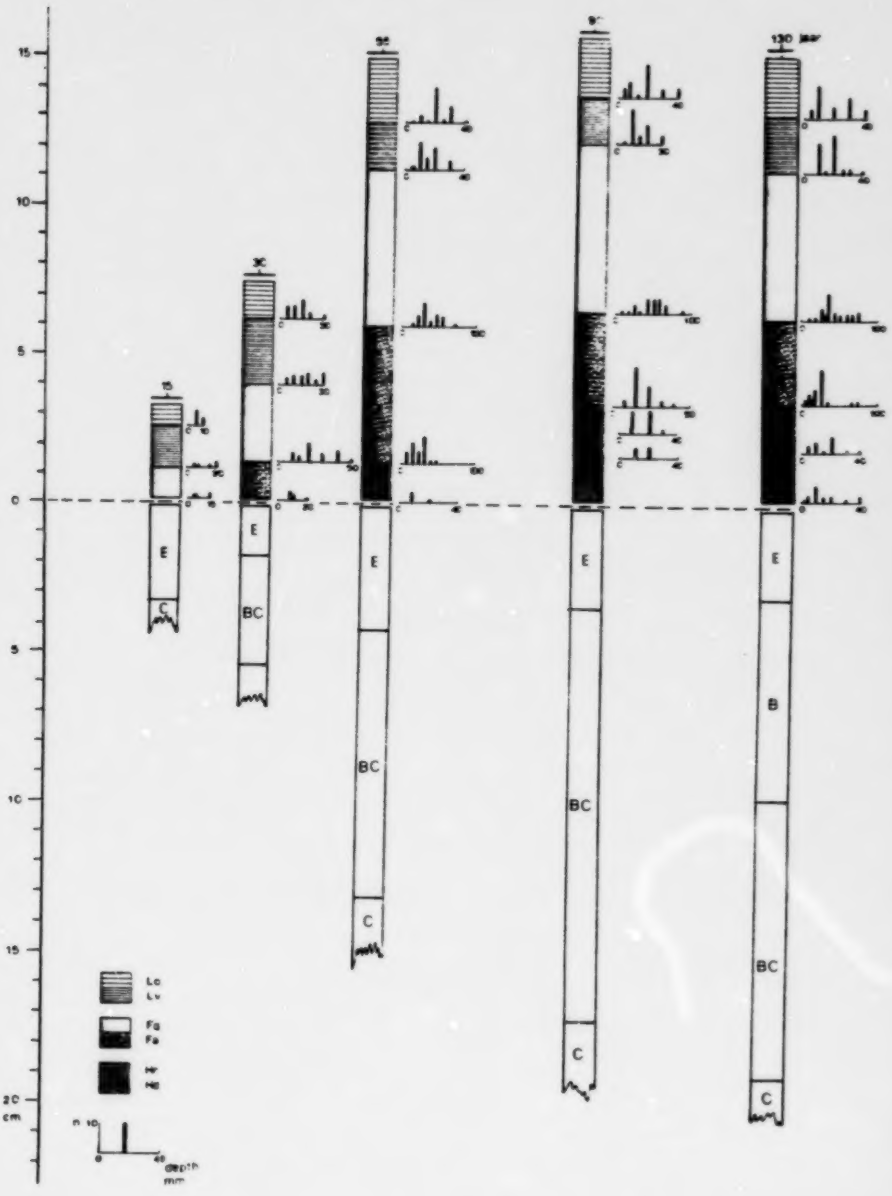

Fig. 2 Standard soil profiles including frequency diagrams of thicknesses of organic horizons for each of the Scots pine stands (Mettivier Meyer et al., 1986).

ON THE CHARACTERISTICS AND MANAGEMENT STRATEGIES OF SUBALPINE CONIFEROUS FORESTS IN SOUTHWESTERN CHINA

JIANG YOUXU

Professor
Institute of Forestry
Chinese Academy of Forestry
Beijing, CHINA

FDC: 188: 174.7: (510)

Summary

The subalpine coniferous forests located on the border of the Xizang Plateau (Tibet) differ in many aspects from the boreal coniferous forests. They are rich in species of the genera *Abies* and *Picea*. A number of various mixed coniferous forests are formed by several species of the genus *Abies* as well as *Picea* because of the overlaps of their distributions; The paleo-hygro-thermophytic flora, elements of lianas and epiphytes and mosses growing on the bark of the trees are extremely important in the sense of community genetics and development. The associations with the same subediphycator layer are combined in a so-called "Circle" which reflects and indicates the micro-climate, soil properties, plant compositions and the succession process more obviously than the ediphycator layers. The silvicultural and ecological characteristics and the management strategies of these forests are discussed.

Keywords : Subalpine coniferous forest ; Southwestern China.

Introduction

There is a large area of subalpine coniferous forests mainly composed of *Picea* and *Abies* in the higher elevations of the Hengduan Mountain region located from 26°to 34°N. and 98°40'to -140°E. in southwestern China including western Sichuan Province and northwestern Yunnan Province, Such subalpine forests are not common in other parts of the world. As this region is located on the border of the Xizang Plateau (Tibet) with precipitous peaks and deep gorges ranging in altitude from 500 m to 4500 m. The basal zone is subtropical evergreen broadleaf forest and the upper limit is formed by the alpine zone which is followed be the everlasting snow belt. The climatic conditions in the subalpine zone, from 2700 m to 3900 m above sea-level, are characterized by cool and humid climate, which is suitable for the development of coniferous forests composed of spruce and firs. Thus, such a coniferous forest belt is formed in a region with low latitude and high elevation in the northern hemisphere. In comparison with the boreal coniferous forests in the cold temperate region, the flora elements and community properties of these subalpine coniferous forests are quite different.

The vertical vegetation zones and the vegetation differentiation

The subalpine coniferous forest belt, as a part of the vertical vegetation zonation of the region, is an entity of historical interactions between bioma and physical factors such as topography, climate etc., which are determined by the three-dimensional effects of latitude, longitude and elevation. The latitude mainly determines the properties of the basal belt and its potential possibility of presentation, the elevation usually determines the actual circumstances of the basal belt as well as the whole vertical vegetation distribution, and the longitude affects the variability and diversity of the vegetation types of the all vertical belts by means of changing the status of the moisture and heat through upper air circulation of westerlines. Beside the model which represents the typical vertical vegetation zonation of this region, there are also some other vertical distribution patterns with differences between them. The general model of the vertical vegetation zonation is as following :

ALTITUDE (m)	VEGETATION TYPES
2000	The evergreen broadleaf forests belt
2000-2500	The deciduous broadleaf forests belt
2500-3000 (2700)	The coniferous/broadleaf mixed forests belt
2700-3900	The subalpine coniferous forests belt
3900	The alpine shrubs and meadows belt

The flora compositions and the community properties of the subalpine coniferous forests

In the described subalpine forests belt, the most abundant tree species are spruces (*Picea sp.*) and firs (*Abies sp.*). As the plateau raised rapidly in the tertiary period causing vertically and horizontally differing natural conditions in the southeastern folded border region of Xisang Plateau, more variations have occurred among the phenotypes of the *Picea* and *Abies* species. The spruces are *Picea purpurea*, *P. asperata*, *P. retroflexa*, *P. brachytyla*, *P. brachytyla var. complanata*, *P. likiangensis var. balfouriana* etc. and the firs are *Abies faxoniana*, *A. georgei*, *A. squarmata*, *A. forrestii*, *A. ernesti* etc.

The coniferous forest with its different dominant species seems present in general no obvious differences in ecology and community properties. Despite the main genera of the undergrowth, herbs and mosses of the subalpine coniferous forests such as *Betula*, *Sorbus*, *Vibernum*, *Lonicera*, *Ribes*, *Rubus*, *Prunus*, *Spiraea*, *Galium*, *Equisetum*, *Geranium*, *Viola*, *Oxalis*, *Caltha*, *Athyrium*, *Dryopteris*, *Sphagnum* etc. which are same as those of the boreal coniferous forests, there are also many paleo-hygro-thermophytic flora components, and the total number of plant species is much higher than that of the boreal coniferous forests, because in the subtropic regions the winter is warmer (the average temperature of January is -5° to -3°C), rainfall concentrates in summer, atmospheric humidity is higher, and the floristic components from Middle and Eastern Asia, Himalaya, Indo-Malaysia etc. are also present

there. Some paleo-hygro-thermophytes like *Sinarundinaria chungii* and many high, tree-like shrubs such as *Rhododendron przewalskii*, *Rh. aganiphyllum* etc. constitute the dominant species of the understory; these species are absent in the boreal coniferous forests. As the humidity of the air is very high in subalpine forest stands, there are a number of extra-layer plants, like *Usnea longissima*, hanging on trees and shrubs, and many mosses such as *Neckera pennata*, *Leucadon flageliformis*, *Metzgeria furcata*, *Plagiochila schtschena* etc. growing densely on the bark of the trees; some moss species living on soil surface but also grow on trees. Therefore the community physiognomy of the subalpine coniferous forest is unique and in contrast to boreal coniferous forests. It can therefore be considered that the flora of the subalpine forest in this region has been formed by three processes :

- the convergence of external flora components;
- the vertical differentiation during the orogenic movement;
- the internal differentiation within the mountain region accompanying the ecological isolation in southeastern China.

Another important community characteristic of subalpine coniferous forest in this region is the existence of a dominant subediphicator layer (shrub layer or herb or moss layers) in forests *(shrubs : Rhododendron, Sinarundinaria, Quercus*; mosses : *Actinothuidium hokkeri*, *Hylocomium proliferum*. They have an important influence on the microclimate, the soil, the species composition and the development characteristics of the community. Sometimes they have even a more obvious effect than ediphicator layers - the tree layers. The communities (or forest types), which have the same subediphicator layer can be attributed to a same "circle", and their relationship in community genetics is closer then the relationship between the different associations (or forest types) in the same tree species. The relationship between associations and "circles" in the classification of subalpine coniferous forests in this area is shown in tab. 1.

Because of the diversity of the flora and and the characteristics of the communities of the subalpine coniferous forests in this area, we can observe that the development is relatively independent, although the genesis has a close relationships with boreal coniferous forests in the cold temperate zone.

The Forest Characteristics of Subalpine Coniferous Forests

The structure of the forest stands is more complex in subalpine coniferous forest of this area than that in boreal coniferous forest stands; they often appear multi-storied and of different ages. Except in forest types on extreme sites, such as *Abietum casiopeso-rhododendrosum*, the standing tree storey includes at least two or even more substoreys, and each sub-storey may includes two or three generations.

The subalpine coniferous forest stands in this area are generally mature or over mature and their age is often more than 200 years. Mature and over mature forests cover about 81 % of the in total forest area and 90 % of the total standing volume. Except *Abies georgei*, *A. delavayi* and *Picea purpurea*, which are extremely tolerant to shade, all the others species like *Abies fabri*, *A. forrestti*, *A. squarmata*, *Picea asperata*, *P. likiangensis*,

Table 1: The relationship between associations and circles in community classification

		FORMATION			
Site type	Circle	*Abieta*	*Piceeta*	*Betuleta*	*Querceta*
Acropsychro-sciohygrophilic	Rhododendron	Abietum casiopeso-rhododendrosum			
		Abietum caricoso-rhododendrosum			
		Abietum hylocomioso-actinothuidioso-rhododendrosum			
Sciohygrophytic	Hylocomium-actinothuidium	Abietum hylocomioso-actinothuidiosum	Piceetum hylocomioso-actinothuidiosum	Betuletum hylocomioso-actinothuidiosum	
Sciohygrophytic	Sinarundinaria	Abietum hylocomioso-actinothuidioso-sinarundinariosum	Piceetum pteridioso-sinarundinariosum	Betuletum hylocomioso-actinothuidioso-sinarundinariosum	
		Abietum pterioso-sinarundinariosum			
		Abietum carioso-sinarundinariosum	Piceetum equisetoso-sinarundinariosum		
Semihygro-mesophytic	Quercus	Abietum quercosum	Piceetum quercosum	Betuletum quercosum	Quercetum primulosum
Semixero-mesophytic					Quercetum adianthosum

P. brachytyla, *P. wilsonii* etc. can not tolerate shading after the age of three to five years. Therefore natural regeneration in these coniferous forests can generally be considered from acceptable to bad, but it is generally better on forest edges and on open land, than in the inner of the forest stands. These characteristics of natural regeneration have an important significance for forest management decisions in this area.

On the basis of integrated research results obtained in the subalpine coniferous forests of this area, the general model of water balance of stands and clear-cut land is the following :

Watershed	Precip. (P)	Runoff (R)	Evpt. E=e1+e2+e3			
			e1	e2	e3	E
Forest land	100	60-70	15-20	15-20	15-20	30-40
Cutted land	100	30-40	60-70	-----	-----	60-70

e1 : E. of soil and floor; e2 : canopy intercept; e3 : tree transpiration.

Because most of the forest stands are multi-storied, unevenaged and have a high degree of canopy closure, they can intercept more rainfall and the forest floor has a good ability of absorption and a greater holding capacity. The surface runoff of these forests is consequently very small. Such a high efficiency water conservation is extremely important in the forest areas located in the upper catchment areas of the Yangtze River, the Nu River and the Lanchang River, where most of the forests grow on steep slopes.

Moreover, experiments and surveys showed that the speed of decomposition and accumulation of the soil organic matter is higher in our subalpine coniferous forests than in that of boreal coniferous forests in the cold temperate zone. The shrubs and herbs grow very flourishing after a clear-cut. When determining management methods, e. g. tending of young stands from natural regenerations, these factors should be considered.

The Management Guide-lines of Subalpine Coniferous Forests

When we determine forest management guide-lines for this area, we should consider the following three aspects :

1. - There are complete vertical vegetation zonations which are rarely seen in the other part of the world, abundant forest types and community types, a high complexity and diversity of the compositions of fauna and flora, and the subtropical subalpine coniferous forests which are comparable with boreal coniferous forests. All these are of extremely high interest for scientific studies.

2. - The forest stands in this area have a important role for the conservation of soil and water, as it is particular important to maintain a sufficient level of agricultural production in the middle and lower course of the Yangtze River and in the lower course of the Nu and the Lanchang River.

3. - The standing timber resources in the subalpine coniferous forests are quite important but we should exploit them very reasonably if we need the wood for our economy.

For this reason, forest management strategies in this area should be :

1. - In order to preserve the vertical zonations of vegetation with their inherent differences and vegetation types, a certain number of nature reserves must be planned and established. The area of each nature reserve should generally be not lesser than 200 000 ha. Research on these ecosystems can than be conducted in the nature reserves.

2. - In order to maintain or to improve the role of the conservation function for soil and water of the forests in this area, the ridges of mountains and hills, extremely steep slopes (steeper than 35°), the borders roads and river and the upper limit of the forest should be considered as protection forest with restricted cutting.

3. - In forest stands suitable for exploitation, which are growing on slopes lesser than 35° the cutting practices should be very small clear-cuts (strips or plots) or selection cutting and sufficient seed trees must be preserved. Natural regeneration should be promoted as well as planting.

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DYNAMICS IN MATURING SCOTS PINE MONOCULTURES IN NORTH-EAST BELGIUM

D. MADDELEIN, N. LUST, S. MEYEN & B. MUYS[1]

Laboratory of Forestry
State University of Ghent, Belgium

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SUMMARY

The State Forest Pijnven, created early this century by afforestation with Scots pine *(Pinus sylvestris L.)* of heathland areas is now characterised in most stands by an important ingrowth of deciduous tree species. Ingrowth is dominated by red oak *(Quercus rubra L.)* and black cherry *(Prunus serotina Ehrh.)*, both being species originating from North-America. Deciduous ingrowth in the pine stands profoundly influences herbal composition of the stand. *Deschampsia flexuosa (L.) Trin.*, abundant in all older pine stands, disappears when deciduous trees settle and species diversity, already low in the pine stands, further diminishes. Important oak and cherry regeneration is depending on the presence of seed trees in the vicinity; when lacking, a new pine generation manages to settle. A good red oak regeneration can be useful as a basis for stand conversion towards a mixed, uneven-aged deciduous forest type, but in many cases this possibility is hampered by massive invasion of black cherry, preventing all other species to regenerate.

RESUME

La forêt domaniale Pijnven située au Nord-Est de la Belgique, a été créé au début du XXième siècle par l'afforestation d'un grand terrain de bruyère. Cette afforestation s'est presque entièrement réalisée avec le pin sylvestre *(Pinus sylvestris L.)*. Aujourd'hui, ces forêts se charactérisent souvent par une importante régénération naturelle d'essences feuillus à l'intérieur des peuplements de pins. Deux espèces de provenance nordaméricaine dominent cette régénération, à savoir le chêne rouge *(Quercus rubra L.)* et le cerisier tardif *(Prunus serotina Ehrh.)*. L'introduction d'arbres feuillus modifie très fort la composition du strate herbacé. Par conséquent la canche flexueuse *(Deschampsia flexuosa (l.) Trin.)* , abondamment présente dans les peuplements de pins, disparaît presque entièrement et la végétation, déjà très pauvre en espèces,

[1] Research conducted for the account of the Belgian State - Services of the Prime Minister, Programmation of Science Policy - and of the Commission of the European Communities.

appauvrit encore plus. La présence d'arbres-mères aux alentours des peuplements est une condition sine qua non pour l'obtien d'une bonne régénération d'arbres feuillus dans les peuplements. En cas d'absence de ces arbres, une nouvelle génération de pins sylvestre à la fin réussit à se développer sous le vieux peuplement. Une bonne régénération de chêne rouge peut se révéler utile comme base d'une conversion de peuplements purs vers un type de forêt d'arbres feuillus mixte et inéquienne. Mais souvent, cette évolution est empêchée par l'invasion massive du cerisier tardif, mettant ainsi obstacle à la régénération de toute autre espèce.

INTRODUCTION

The North-Eastern part of Belgium, known as the Campine region, is characterised by its poor, sandy soils. Various human activities have resulted into the disappearance of the former vegetation type (oak-birch forest) and have led to the presence of vast heathland areas. In an attempt to rehabilitate this area, large parts were reafforestated starting from the mid of last century.The reafforestation was executed almost exclusively with Scots pine *(Pinus sylvestris L.)*. Today, secundary succession trends are fully noticeable in numerous maturing Scots pine monocultures *(VAN MIEGROET, 1985; LUST, 1987; DE SCHEPPER, 1988)*. Several deciduous tree species have settled under the pine canopy and can prove to be useful as a basis for a second generation forest.

SITE DESCRIPTION

This research was executed in the state forest Pijnven situated near Hechtel-Eksel (fig. 1).

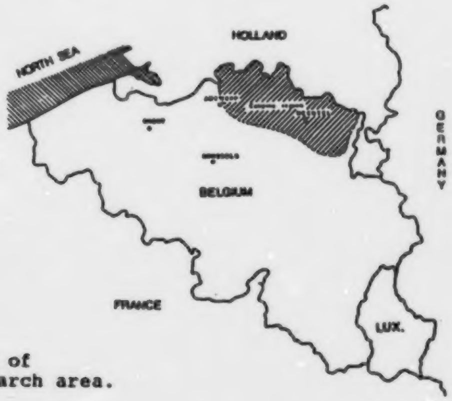

Figure 1 : Location of the research area.

The state forest Pijnven covers about 800 hectares and was established early this century on former heathlands. Part of the forest is situated on continental sand dunes.

Forest soil is very poor, with sand fraction (particles ≥ 50 µm) accounting for about 90 % of the total grain size distribution. Before afforestation, the soil was completely ploughed (up to a depth of 30 cm) to break the iron-accumulation horizon. Later lupines were grown for three consecutive years in order to fix nitrogen in the soil. Finally an additional fertilization with phosphorus and lime was supplied. The afforestation was executed by employing a geometrical pattern dividing the forest in rectangular stands with a surface of 4 to 5 hectares. The stands are separated by broad roads surrounded by a deciduous tree species shelterbelt. The shelterbelts originally consisted of various tree species, but are nowadays dominated by red oak *(Quercus rubra L.)*.

Later, especially beyond 1930, most reafforestations were executed with Corsican pine *(Pinus nigra Arnold subsp. laricio)*, that shows greater yield than Scots pine and by now occupies over 50 % of the total forest area. Scots pine only amounts to 35 % of the total forest area, but the bulk of those stands are over 60 years old and ready for conversion.

MATERIALS AND METHODS

In order to study secundary succession trends in Scots pine monocultures, a number of stands, representing different succession phases, were selected. A short overview of these stands is presented in table 1.

For the inventory of tree species, a number of plots was established in each stand. For all trees higher than two metres, diameter at breast height (dbh) and total tree height were recorded. Plant sociological releves were performed using the Braun-Blanquet method.

The organic soil layer was described by the thickness of litter (L), fermentation (F) and humus (H) horizons. The biomass of the holorganic layer was measured by harvesting six 0,25 m^2 plots.

Mineral soil was analysed on combined samples collected in every stand (sampling depth 10-15 centimetres), and the following chemical analysis were performed : carbon content (Walkley & Black); nitrogen (modified Kjeldahl); Ca, K and Na (flame photometry); Mn, Mg, Fe, Al (atomic absorption spectrometry); SO4 and Cl (ion chromatography) and P (colorimetry).

The inventory was conducted during spring and summer 1988. Soil samples were collected in December 1988.

Statistical data processing was carried out with the programm BIOMECO, developped by the biometric group of the Centre d'Ecologie

Végétale et Evolutive (CNRS) at Montpellier, France.

Table 1 : Main characteristics of the research stands.*

Stand number	Stand age	Domin. sp.	Main characteristics
1	45	Scots pine	monoculture, established after clearcutting of poor growing 30 year old pine stand ; on former heathland
2	56	Red oak	monoculture established through sowing under 25-year old pine stand; 1959: removal pines ; located on blown-over podzol profile
3	69	Scots pine	monoculture, located on land-dunes
4	75	Scots pine	monoculture, on former heathland
5	69	Scots pine	monoculture, on former heathland
6	69	Scots pine	monoculture, on former heathland

* All stands are first or second generation forests and were afforestated early this century.

RESULTS AND DISCUSSION

Plant sociological inventory

Before reafforestations, two plant communities covered the Pijnven area *(Rogister, 1953)* :

- The *Callunetum-Genistetum* TOXEN (1937) on the podzolic soils ;
- The *Corynephoretum-canescentis agrostetosum caninae* TOXEN (1937) in the drift sand area.

Sparsely, some relict species of the original oak-birch forest were present.
Already in the early fifties, it was difficult to distinguish both communities in the field, since the afforestation had led towards a more uniform species composition in the whole forest.
Species like *Corynephoretum canescens, Festuca ovina, Agrostis canina* and *Poa nemoralis* were still common 30 years ago, but have by now disappeared from all research stands (table 2).

Current species presence is very limited. In all plots together, only seven herbaceous species were present. Dominating herb species in all stands is *Deschampsia flexuosa*, sometimes covering over 80 per cent of the soil. Spontaneous regeneration of tree species is dominated by black cherry and red oak, except for

stand 3 where Scots pine is most widely spread. Only in this stand, natural evolution is tending towards a second generation forest dominated by Scots pine, while elsewhere deciduous species will prevail. Regeneration of autochthonous tree species (birch, oak, rowan, ...) occurs only on a limited scale, due to the low seed tree presence in the surroundings and the very high browsing damage on the seedlings present. In fact, selective browsing by roedeer effects all deciduous trees with the exception of black cherry.

Table 2 : Species presence in the research stands (method Braun-Blanquet).

Stand		1		4				2			3		
Plot		1	2	3	4	5	6	7	8	9	10	11	12
Species	Symbol												
Betula pubescens Ehrh. (juv.)	BET	+	+	-	+	-	-	-	-	-	+	-	-
Calluna vulgaris (L.) Hull	CAL	-	+	-	-	-	-	-	-	-	-	-	-
Carex pilulifera L.	CAR	-	-	-	+	-	-	-	-	-	-	-	-
Deschampsia flexuosa (L.) Trin.	DES	5	5	1	2	2	1	+	+	+	4	5	5
Dryopteris carthusiana (Vill.) H.P. Fuchs	DRY	1	+	+	+	-	+	-	-	-	+	+	+
Epilobium angustifolium L.	EPI	+	+	-	+	+	-	-	-	-	+	+	-
Frangula alnus Mill. (juv.)	FRA	+	+	-	-	-	-	-	-	-	-	+	+
Molinia caerulea (L.) Moench.	MOL	-	-	-	+	-	-	-	-	-	-	-	-
Pinus sylvestris L. (juv.)	PIN	1	1	+	1	+	+	+	-	-	1	1	1
Prunus serotina Ehrh. (juv.)	PRU	+	+	+	1	+	+	+	+	+	+	+	1
Quercus robur L. (juv.)	QRO	-	+	-	-	-	+	-	-	-	+	+	+
Quercus rubra L. (juv.)	QRU	+	+	+	+	+	1	+	+	+	+	-	-
Sorbus aucuparia L. (juv.)	SOR	+	-	+	+	+	+	-	-	-	-	+	-
Vaccinium myrtillus L.	VAC	-	+	1	1	-	+	-	+	-	-	-	+

Stand inventory

The results of the stand inventory are given in table 3. In this table all tree species with a diameter of less than 8 centimetres at breast height are excluded.

Stand 1 is showing extremely good yield for Scots pine on this soil type, whereas stand 2 is of very poor quality. Average tree volume in stand two is about equal to that of the naturally established red oaks in stand 4. This extremely low standing crop is probably caused by the doubtful origin of the oak seeds. Stands 3 to 6 are mature Scots pine stands. Typical for all except for stand 3 is the presence of an important naturally established deciduous tree layer. This understorey is composed by only two species : red oak *(Quercus rubra L.)* and black cherry *(Prunus serotina Ehrh.)*, both being North-American species. In fact, the trees mentioned in table 3 (dbh > 8 cm) only form a small fraction of the total consolidated natural regeneration (table 4).

A distinct difference can be noticed between the total amount of ingrowth present in every stand. Stand 4 is dominated by red oak, while black cherry largely dominates stands 5 and 6. In all cases, black cherry is dominating the lowest diameter and height

classes, often showing a shrubby habitus. Since it is doubtful that black cherry can produce valuable timber on these soils, most attention in forest management is paid to red oak.
When comparing the global red oak regeneration, only stand four can be called satisfactory. Here, an important fraction of the trees are present in upper diameter classes, and some trees have even reached the pine canopy. Moreover, a considerable oak fraction is present in the understorey of this stand (table 4). In the other stands, red oak regeneration is limited because massive regeneration of black cherry inhibits new oak settlements.

Table 3 : General features of the research stands.

Stand	Tree Species	Stem number (with dbh≥8cm)	mean dbh (cm)	mean height (m)	Basal area (m2/ha)	Standing volume (m3/ha)
1	Scots pine	1100	18.1	15.2	29.1	210
2	Red oak	695	12.7	13.1	12.7	67
3	Scots pine	413	27.5	19.4	24.8	213
4	Scots pine Red oak Black cherry	220 335 70	29.1 11.8 9.7	20.6 12.0 9.3	15.0 5.1 1.1	135 22 2
	Total	625	17.6	14.7	20.2	159
5	Scots pine Red oak Black cherry	338 88 113	25.7 8.9 9.2	17.8 8.6 6.6	17.9 0.5 0.8	145 2 2
	Total	539	19.5	14.0	19.2	149
6	Scots pine Red oak Black cherry	334 127 27	27.3 9.2 8.0	19.5 9.5 7.0	19.8 0.9 0.1	173 3 0
	Total	488	21.9	16.5	20.8	176

Table 4 : Diameter and height distribution of the deciduous substorey (height ≥ 2m and dbh ≤ 8cm)

Stand	Species	Diameter class (cm)							Height class (m)								
		0-5	5-8	8-11	11-14	14-17	17-20	20-23	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	TOTAL
4	oak cherry	435 285	250 155	150 35	105 15	30 0	20 0	10 0	155 280	130 85	210 70	195 35	175 20	110 10	10 0	15 0	1000 490
5	oak cherry	175 1312	188 425	75 88	0 0	0 0	0 0	0 0	63 650	63 725	250 425	50 25	13 0	0 0	0 0	0 0	439 1825
6	oak cherry	320 550	374 113	73 0	13 0	0 0	0 0	0 0	53 380	140 180	320 80	207 13	60 0	0 0	0 0	0 0	780 653

Tree age analysis using a Pressler-corer in stand four showed that the red oaks varied in age between 16 and 43 years, black cherry between 16 and 27 years. Forest management records mention that in this particular stand, black cherry was planted in 1954. Obviously, those trees failed to survive and were replaced by naturally established trees. Age analysis proves that red oak regeneration started when the pine stand was only 32 years old and that the regeneration period took very long.

S o i l   a n a l y s i s

Organic layer

Analysis of variance could not detect any significant differences between the thickness and biomass of the holorganic layer of stands 1, 2, 3 and 4. Nevertheless, stand 1 contains about 30 tonnes less dry organic matter per hectare than the other stands (table 5). In general, organic matter accumulates at a rate of 1,5 tonnes per hectare per year. Current annual litter input is highest in both stands 1 and 2. In stand two, decreasing litter production by the maturing pine trees, is fully compensated by the important deciduous litter contribution of the ingrowth *(Maddelein & Meyen, 1989)*.

Table 5 : Soil characteristics of the research stands.

Fractions	Subject	Stand 1	Stand 2	Stand 3	Stand 4
Mineral Horizon (10-15 cm)	pH H2O	4.03	4.21	4.27	4.14
	pH KCl	3.09	3.31	3.49	3.46
	C (%)	1.23	1.06	0.81	0.64
	N (ppm)	151	181	180	187
	Na	54	60	59	67
	K	22	24	42	41
	Ca	44	43	38	57
	Mg	3	3	3	4
	Al	182	209	216	142
	Fe	209	173	250	212
	Mn	0.3	0.2	0.2	0.3
	P	10.6	3.5	4.2	7.7
	SO4	98	89	109	95
	CEC (meq/100g)	4.22	4.40	3.63	2.85
	Base Cation Saturation (%)	2.04	1.47	1.05	0.77
Organic Horizon	Thickness (cm) L-Layer	0.2	0.8	0.9	0.4
	F-layer	5.3	4.8	2.2	5.0
	H-layer	1.2	2.1	4.5	1.9
	Total biomass (tonnes.ha-1)	76.2	105.3	103.9	107.7
	Annual litter input (kg.ha-1)	5049	4849	4100	4560

Significant differences between stands are detected for thickness of litter (α = 0,01), fermentation (α = 0,001) and humus layer (α = 0,001). Stands with deciduous species present (2 and 3) possess a thicker litter layer than pine stands. The red oak stand differs from the other stands through the development of an important humus horizon and a thin fermentation horizon. In pine stands, a thick fermentation horizon usually develops under the influence of *Deschampsia flexuosa (Mettivier Meyer et al., 1986)*.

Mineral soil

Of all analysis performed on the mineral soil fraction, only few indicated significant differences between the stands.
Total carbon content differed very significantly between the stands. This is explained by a higher humus content in the upper soil layers of stands 1 and 2, originating from the spodic horizon being disturbed by ploughing before afforestation (± 1905). Cation exchange capacity and base cation saturation are very low, stressing the extremely poor soil conditions.

O r d i n a t i o n a n d c l a s s i f i c a t i o n

In the 4 investigated stands, a total of twelve plant sociological releves was completed (table 2). Following the Braun-Blanquet scale, species presence in every plot was appreciated according to seven classes, going from (example for *Calluna vulgaris*) CAL1 : absent, to CAL7 : soil coverage 75-100 %.

<u>Table 6</u> : Coverage classes of woody vegetation in upper and understorey.

Plot		1	2	3	4	5	6	7	8	9	10	11	12
Upper storey	Code												
Q. rubra	BAM	1	1	1	1	1	1	6	6	6	1	1	1
P. sylv.	BPI	5	5	4	4	4	4	1	1	1	5	5	5
Under storey	Code												
Q. rubra	NAM	1	1	5	5	5	5	2	2	2	1	1	1
P. sylv.	NPI	1	1	1	1	1	1	1	1	1	1	1	1
P. serot.	NSE	3	3	4	4	4	4	1	1	1	2	3	5

Then, it was tried to explain species composition by a number of ecological variables. The apparently most important variable was the tree species composition in upper- and understorey. This variable is responsable for light penetration towards the soil vegetation, and possibly also for the nutrient status of the forest soil. As for the herbaceous vegetation, the tree species coverage was estimated by classes going from 1 (0 %) to 7 (75-100% coverage). This resulted in a matrix presented in table 6.

The tree coverage matrix was crossed with the original species presence matrix and the resulting matrix was subjected to an factorial correspondance analysis, with the plots as supplementary variables (figure 2).

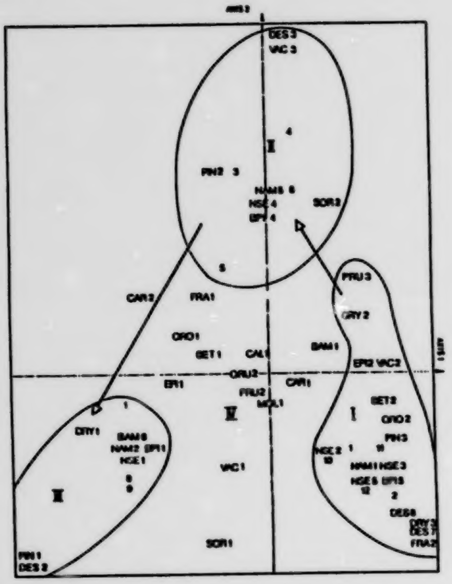

Figure 2 : Factorial Correspondance Analysis of the crossed matrix of herbal vegetation and tree cover. Plane of the first and second factorial axes with indication of the plots as supplementary variables (1 to 12), main vegetation types (I to IV) and the successional chronosequence (arrows).

This procedure was followed by the classification of Ward, based on the euclidic distance between points and resulting in the encircled groups of the figure. The first factorial axe explained 57 % of total variability. The negative edge of the axe was mostly formed by the absence of pines in the upperstorey, the dominance of red oak and the absence of black cherry in the understorey. Herbal vegetation is very sparsely present, pine and *Dryopteris carthusiana* being absent. Stand 2 is located in this area (vegetation type III). The positive end of the first axe is characterised by a relatively dense pine upperstorey, accompagnied by a more or less important presence of black cherry in the substorey. Red oak is absent. The herbaceous vegetation is abundant and dominated by *Deschampsia flexuosa*. Dispersed seedlings of Frangula, Pinus and Quercus robur are evenly present (vegetation type I). The second

axe explains 33 % of the variation. This axis is mainly formed by a, somewhat less dense, pine canopy and a dense substorey consisting of oak and cherry. The herbal vegetation is characterised by the presence of Vaccinium, Molinea and Sorbus and the restricted presence of Deschampsia and pine seedlings (vegetation type II).

Vegetation group IV consists in the absence of the species Molinea, Vaccinium, Sorbus, Epilobium, Betula, Calluna, Carex, Frangula and Quercus robur. This group is not typical for any stand ; these species can be absent in any forest type.

A successional chronosequence starting from group I and passing through group II to end up in group III can be distinguished and is probably the general scheme for a first generation of pine planted on heathland in this region. However, the final stage with absolute dominance of red oak, here artificially established in stand 2, will probably not be reached. It is more likely that future forest generation will be dominated by both oak and cherry, with cherry taking the overhand in the younger stands where oak has not settled by now.

Additionally, an identical analysis was performed in order to assess the importance of soil parameters for explaining the vegetation types. As could be expected from the analysis of variance, the classification detected high similarities between the stands.

SYNTHESIS

In the young, man-made Pijnven forest, succession is widely dominated by exotic tree species.
Globally, the older pine stands are characterised by an important presence of deciduous trees in the understorey. Red oak and black cherry are by far the dominating species in this layer.

When deciduous species manage to settle in homogeneous pine stands, *Deschampsia flexuosa* rapidly disappears to survive only in remaining sun flecks *(Packham & Harding, 1985)*.

After canopy closure, bilberry *(Vaccinium myrtillis)*, a shade tolerant species, is likely to become dominant in the herbal stratum, although the expansion of Vaccinium-groups occurs at a relatively low rate. Other herbaceous species will settle very sparsely and will be confined to special sites (sun flecks, disturbed soil, ...). Overall, the biggest part of the soil will probably lack herbal vegetation, as it is the case for stands 2, 4, 5 and 6.

Seed origin of both ingrowing tree species are to be found in the deciduous fire-belts from where seeds are dispersed in the stands by birds and rodents. Where these fire-belts are lacking (stand 3), settlement of deciduous species is very limited and finally a new pine generation settles.

Both cherry and oak germinate and grow up under the pine canopy without any difficulty although they are normally considered as rather shade intolerant *(Runkle, 1985 ; Auclair & Cottam, 1971)*. However, *Crow (1988)* and *Stroempl (1987)* already mentioned the good growth conditions for red oak under pine canopies.

Black cherry was introduced on a limited scale in the Pijnven area in the early fifties. Today about 3000 hectares are colonised by this species. Similar massive invasions are mentioned by *Borrmann (1988)*, *Eysackers & Oldenkamp (1976)*, *Smith (1975)* and *Lust (1987)* for pine forests, and by *Auclair & Cottam (1971)* for North-American oak stands. This process causes enormous problems for forest management, since forest regeneration is in many cases impossible without clearcutting the pine stand and subsequently elimination of black cherry. The great vigour of this species (enormous sprouting capacity) has made this objective very hard and costly to attain. Overall, mechanical root excavation has proved to be the best method and is now most practised in Belgium. This method causes an intensive soil cultivation and creates good conditions for Scots pine natural regeneration. If this regeneration is unsuccesful or unsatisfactory, artificial regeneration (Scots pine, Corsican pine, Douglas fir, ...) can be used.

For all stands with red oak dominating the understorey, forest management is aiming at an indirect conversion towards a red oak dominated, uneven-aged, mixed forest. The remaining pines pose little threat to the understorey development, and will slowly be removed in the coming decades as they will slowly loose vigour.

Parts of the stands which are unsuccesfully regenerated can be planted up with different species, according to the gap size and orientation. In this way, reintroduction of autochthonous tree species (pedunculate and sessile oak, beech) in the forest area can be actualised *(Ebeling & Hanstein, 1988)*. Introduction of those species can already be started in rather well stocked pine stands. This technique can avoid the further expansion of black cherry as is illustrated in stand four.

Combination of all possibilities should result in a future forest generation consisting of a more diverse, species rich, uneven-aged forest providing a versatile number of goods and services for the human society.

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THE FUTURE OF FOREST MANAGEMENT BASED ON RESEARCH RESULTS FROM VIRGIN FORESTS

Dušan Mlinšek

Professor of Silviculture
Department of Forestry

Biotechnical Faculty
University of Ljubljana
Ljubljana, Slovenia, Yugoslavia

FDC: 61: 228.81: 180

ABSTRACT

Virgin forest research permits insights into the true life processes of the forest. Results of this kind of research demand a profound change of forest management in the future. The guidelines of forest management patterned on nature are thereby confirmed and strengthened. The gravest mistakes of today's forest management are brought to attention. The new guidelines for the forest treatment of the future were outlined.

Key words: Virgin forest research, virgin forest structures and functions, forest management patterned on nature, ecosystem tending

INTRODUCTION

Forest management was in the past, and will be in the future, faced with the task of the careful maintenance of forests. That challenge becomes urgent in the face of the cannibalistic forest destruction in the 20th century. This modern destruction is the consequence of human greed on the one side, and a completely erroneous idea about the living forest on the other side. Proof for this statement is among others the fact that the many rich, as well as the poor nations, mistreat the forest. It becomes increasingly evident on the other hand that wood and the many functions of the forest with their mutual influence on mankind becomes ever more important, and that the mistreatment of forests must be ended.

Forest management, preoccupied with timber production, has forgotten how to observe the virgin forest and to follow the hints of nature. For this reason, forest management of many countries is close to the collapse of an artificially created world of "tree farms" which were born out of thinking in terms of agricultural production. The search for a way out of this disastrous situation leads forest management via the virgin forest out of this deadend street. Through virgin forest research and research of

similar natural ecosystems proceeds the search for the truth about the nature of forests.

Initial research results lead already to reflections about the permanence of the forest when it is in its original state. The virgin forest is by nature a self-perpetuating system. This characteristic is the consequence of population-genetic, or perhaps better termed ecosystem-genetic processes, in the course of long periods of time. Climatic fluctuations and other perturbations "sculpture" forest ecosystems over long times and "prepare" them for the unforeseeable.

Such a forest interests us more and more, especially its mechanisms. That is based on the following thought: As a natural entity, the virgin forest fulfills spontaneously some demands of man, and perhaps even more than we are conscious of. Man, however, makes also special demands on this forest which cannot be met by the makeup of the virgin forest. Such demands may be specific wood properties, or a more distinctive protective function. That requires to begin with an examination of the validity of the demands made on the forest. Secondly, the question arises which actions, and in which form, must be taken in order not to injure the self-regulating process of the forest. This is the central thought of silviculture patterned on nature. That concept and the new direction has long been formulated in Europe and practiced in a pioneering fashion. The transition to this new kind of, but long recognized, forest treatment patterned on nature requires virgin forest research. It further requires an elaboration of strategies for the transition period which must differ according to site and countries. Current knowledge of virgin forest, based primarily on results of research from Europe and the USA, leads to concrete suggestions as how to treat the forest in the future.

VIRGIN FOREST IS SELF-SUSTAINING AND THE FOREST NEEDS CARE WHICH PERMITS IT TO BE SELF-SUSTAINING

<u>Virgin forest is an indispensable classroom. Life in the virgin forest is self-sustaining and self-promoting.</u>

Results from research in virgin forests indicate that all processes in this kind of forest proceed spontaneously and are self-regulating. Although it provides at the moment merely a narrow window to the extraordinary complex working of a natural ecosystem, virgin forest research shows that it will be impossible to copy such a miraculous creation of nature as is the forest. The more we learn about the virgin forest, the more we admire it, the less appears to us our ability to comprehend it. The forest is a miracle like all creations of nature. The scientific comprehension of the virgin forest as a process is impossible yet necessary. It forces us to search for ways as how to deal with the incomprehensible in order to make it permanently useful without breaking it in the process.

<u>Forest treatment patterned on nature needs the virgin forest as its permanent research laboratory. The technology of silviculture patterned on nature is the cognitive method - the method of the small steps.</u>

If the forest is engaged in a process of uninterrupted reorganization and subject to unforeseeable events, then our methods of treatment must have the same characteristics. Forest treatment patterned after nature rests upon observation. Such observation is followed by careful interventions, which in principle occur over small areas only, that permit to judge objectively the ability of the forest to react. Only the evaluation of the extent of reaction enables us to undertake the next following intervention reflecting the previous experience etc. The cognitive acting, also known from research dealing with behavior, can show us the way. To improve our ability for observation each of the following must contribute: Forestry education, forestry organization, forestry facilities. Forestry education must be forest-oriented. Forestry organization should keep the forester busy in the forest and not in the office. Virgin forest laboratories, as many as possible, should be part of forestry facilities and stay always under intensive observation by scientists and practitioners. Practice of forestry in the office and only with a calculator implies the forester's flight from responsibility and decline of the forest.

THE VIRGIN FOREST STRUCTURES TEACH US HOW TO FORM THE VIRGIN FOREST

<u>Virgin forest is a multi-faceted, richly structured overlapping of life phases - a fine-grained diversity.</u>

Research and observations of virgin forest structures in the forests of the globe provides testimony to the structural richness of the virgin forest. Structural diversity demands diversity of life. Diversity of life increases stability and safety of life processes. The extent of it corresponds to conditions of site. That which represents a high degree of diversity in the North is relatively monotonous for temperate region forests, or tropical forests. The importance of a rich structure becomes better understandable by means of an example. Let's assume that the total biomass in a virgin forest amounts to 2,000 m^3 (or tons)/ha. If converted to m^2 it will result in a layer only 20 cm in thickness. That compact thin layer of wood in this imaginary virgin forest is very diversely structured in a 30-50 m high forest mantle. That rich structure below and above ground exists for exercising its manifold functions. These structures undergo constant change with their coming and going over small areas. Characteristic for the virgin forest is the grouping of individuals and the accumulation of biomass by a few individuals on a small area which projected to a per hectare base amounts to several thousand tons. The multifarious crown structure represents hereby a link unrivaled in its functional effectiveness between atmosphere and soil. Large amounts of biomass predominate in the virgin forest depending upon site. A virgin forest without large amounts of biomass cannot survive. This vital amount

is formed by the individuals of the optimal phase. Individuals belonging to phases preceding or following the optimal phase are usually interspersed occupying small areas. The individuals of all developmental categories are mutually intertwined in the virgin forest. The great diversity is promoted especially through overmature and dying individuals. The multiplicity of its functions increases with increasing age of a tree. That makes its presence of special interest.

The transition from one into the next life stage of the individual is gradual. That is particularly true for the aging processes under circumstances where trees of the virgin forest reach a great age and ecologically seen never become old or non-functional. Forest in a youthful stage occupies a relatively modest position and is inconspicuous in the virgin forest. The dominance of individuals producing large amounts of biomass, the special position of younger individuals, and the relatively modest but structurally important and diversity promoting share of dying individuals are key elements in the life of the virgin forest. Recognition of these elements goes beyond their importance for our future care of the forest. The virgin forest is an object for basic research including modern research of structures.

The natural laws of virgin forest structures must be observed. Forest management patterned on nature promotes overall stability in the commercial forest through structure and through diversity of life. Every action in the forest should promote the diversity of vegetal and faunal habitats.

The continual existence of the virgin forest is the guarantee for successful compliance with the natural laws governing it in the commercial forest. One of the sins committed in the commercial forest is the homogenization of its structure. The commercial forest patterned on nature needs according to site functional biomass that is highly structured. The forest pseudoscience of clearcut and age-class forest, just as similar concepts, has to give way in research and practice to more individualized silvicultural treatment. Large, naturally structured volumes are the best guarantee that for example forest decline and similar unforeseeable phenomena cannot destroy the forest. The commercial forest contains too much young forest and suffers from a distinct deficit of old-growth. What is needed in the commercial forest patterned on nature is a larger share of "scrutinized" old-growth. Such old-growth serves to pass on its "experience" to future generations if viewed from the standpoint of population genetics and ecology.

The subordination of silvicultural measures to schematic prescriptions of regulating spacing, and moreover in the monocultures, is a clumsy action against nature. The forester works with an order made by him. Nature has its own rules of order which fit not always into man-made pigeonholes. We draw lines, nature works with clusters. The forester should observe and also work more with clusters in the future. Nature is an artist with its creations. Its forest structures are an uninterrupted masterpiece. The forester must follow nature and develop a high level of a free silvicultural style for the treatment of the forest. This implies among other things: Increasing the share of the structured optimal phase,

promotion of old-growth with its characteristics of diversity, and holding back the young forest and subordinating it to other life phases.

REGENERATION MUST BE DETHRONED IN THE COMMERCIAL FOREST

The young forest represents a long lasting, hard but secure period of life in the virgin forest.

Regeneration in the virgin forest is a permanent process where every species cares for its progeny. These processes are barely known. Young representatives (especially seedlings) of tree species appear in waves, disappear or remain. The further development of "successful" germination is uniquely hard and peculiar. My observations in different parts of the world, for instance, in coniferous forests of the North, in the temperate forest region, in the forests of the American Northwest, in Himalayan forests, the eucalypt forests of the Australian Southeast, indicate that the young forest in the virgin forest appears nucleus-like in spots with more light. Its structure is open, trees are slender and grow slowly. All non-vital individuals are gone. Observations in fir/beech forests show that these "young" trees can become older than 200 years before they continue their development to virgin forest giants. A similar development can be seen in shade-tolerant species but their span of endurance is less. The young forest comes into being somewhat differently in stands which have collapsed over a large area. However, nucleus-like regeneration, long lasting stagnation, and situated in less shaded spots under the canopy of pioneer species resembles the situation in the preserved virgin forest.

A severe selection takes place in the young forest. That is understandable in light of the fact that these little trees have a centurie-long road with many dangers ahead of them. The young forest develops over small areas "protected and subdued" by the old trees. Over small areas because old trees die either individually or in groups. Protected because the "tender" young forest finds protection underneath the old trees. And subdued because the viable young trees are allowed to grow upwards only slowly on account of severe natural selection. The described way is the organic component of a sliding development in population and forest genetics. This road must also be adhered to in forest management.

Regeneration in the commercial forest patterned on nature should be subordinated to the functions of the forest. Regeneration is not a purpose in itself. Natural regeneration takes precedence over artificial regeneration. The mature forest should be regenerated over small areas. The young forest should originate under the protection, selection and "training" by the mature forest.

Removal and regeneration of the mature forest is not permissible from the viewpoint of population genetics, ecology, and long-term economics. Wherever possible, natural regeneration should be used. Forest renewal over a large area leads to ecologically and economically unstable forest

formations which cause already great difficulties for us, and will so even more for future generations. The future renewal of forest shall occur gradually under the effective protection of the mature forest. Regeneration in a commercial forest is only a silvicultural means to an end and not a long-term objective. Accordingly, silvicultural methods have to be devised for forest treatment based on local conditions. Hereby shall establishment of a young forest occur only over small areas, either in form of single trees or groups of trees. The free style of silviculture contains likewise the processes of regeneration strategy over small areas which is subordinated to the long-term silvicultural objectives.

The lesson from the virgin forest and the severe upbringing of the forest plant leads also to the idea that we should not spoil that plant but expose it to a rigid selection process before bringing it into the forest. But that should happen only under the precondition that we want a forest with all the characteristics of forest life and not a plantation of trees.

FOREST MANAGEMENT PATTERNED ON NATURE IS BASED UPON THE NATURAL FERTILITY OF THE SITE

Everything in the virgin forest process is oriented toward unforeseeable events which are characterized by bifurcations and fluctuations. The self-maintenance of the natural fertility of the site guarantees the life processes in the virgin forest. The virgin forest ecosystem is characterized by a distinct ability for attraction and retention which contributes noticably to self-protection and protection system. The preservation of the local fertility of the site and pronounced tendencies for localization of transport in the ecosystem virgin forest are properties to be considered in the management of the forest.

If one wants to understand the life of the virgin forest then one has to grasp it in its entirety. The holistic view leads to success if we begin with old-growth and its phenomena. American researchers (Franklin et al. 1981) have recognized the true value of the departing parts in the virgin forest. Old-growth promises the great diversity through which all life processes in every layer from the soil to the crowns increases in vitality. The recognition that a dead tree is more alive than a living tree, that 80% of life in the virgin forest is sustained by biomass lying on the forest floor, that the true forest soil is only that soil in which woody material such as fallen logs and large tree roots represent major constituents, has far reaching implications. Through it the eye of the forester is directed toward the forest floor. It unfolds a completely new holistic view of the life of the forest. Recognition of such complex development of natural fertility brings also gradual understanding of the mechanisms involved. A highly viable forest ecosystem develops an enormous ability to attract. Like a rolling snowball which attracts ever more snow from its environs with increasing size, so lives and forms the forest its inner structure. The decomposing biomass lives on. It is a continuum from the living tree to the products of decomposition in the soil. Thereby

originate and act synchronously physical, chemical, and biological properties which bring about continuation of the natural fertility. Through the force of attraction are protective mechanisms spontaneously developed inwards and outwards. The "well developed" ability for retention permits the drain of only a small amount of substances to the environment. The losses, however, occur continuously in small quantities. The ecosystem virgin forest is indeed an open system but one with regulated and retentive output. One can therefore justifiably say that the virgin forest is a relatively closed natural ecosystem. The small quantities continuously going to the environs effect through the permanently flowing small quantities a mutually most effective exchange in the form of nutritional and protective functions. Through that, one recognizes the increasing number of functions with advancing age of trees. That requires a different attitude in looking at old-growth and the apparently dead biomass.

Forest management patterned on nature is basing all activity and planning on the natural fertility and singularity of each portion of a site. Safeguarding the primeval protective property of the forest is the uppermost postulate for forest management patterned on nature. All functions of the forest are successfully realized by a well guided furtherance of its protective properties. The localization of transport should receive more attention in the future by science and practice.

In a world of artificially triggered entropy where the environs become a torrent and area of erosion, recognition of the retentive ability of the virgin forest and its protective property, both of which simultaneously imply production, requires a complete change in dealing with the forest, and with the environment in general.

The natural fertility should be maintained. The principal part of caring for the forest will be the proper caring for the old-growth, the "dead biomass". The safeguarding of natural fertility through choice of tree species and the turning away from monoculture is known but applied to seldom. Natural fertility can only be assured when forest technologies tie forest treatment seamless to forest and aquatic ecosystems. Forest technologies of the future have to assume the character of the technologies of small steps. Localization of transport in the forest receives thereby partial attention on account of the fact that harvest leads to log transport but does not result in additional long-distance transport. These measures are also an important part of the free silvicultural style.

CARING FOR THE ECOSYSTEM - THE FOUNDATION FOR THE FREE SILVICULTURAL STYLE

The virgin forest is characterized by pronounced individuality of its members. Each tree is shaped by individual circumstances. These individualists appear mostly in form of small agglomerations. An admirable phenomenon!

Severe selection and structuring of natural populations leads to the formation of populations which can cope with their environs and are capable to react successfully to future changes. We hardly know these properties of virgin forest populations. But so much is for certain: they are present as successful as successful natural constructions which in the course of future processes will pass on their outstanding features to later generations. Their versatile orientation to the unforeseeable can be explained by their remarkable individuality. Moreover, the virgin forest is characterized by its great individuality of the site. A natural population and it components are in principle the mirror image of the site and in this manner a "composition of individualists". The forester should see the forest in this light and act accordingly".

Forest management patterned on nature will be successful if it is going to respect individual aspects in the treatment of the forest. Respect for the natural forest ecosystem and its economic guidance within the bounds of the natural ensues today by means of forest tending.

Forest tending which rests upon respect for the individual and the creative power of its environs is the sole way offering realistic prospects for forest treatment in conformity with nature and economics. Forest tending draws upon lessons from the virgin forest. Its theory and practice lead from the individual via the tending of the stand to the maintenance of its natural fertility. Forest tending becomes a holistic concept and system which has nothing to do with the classic recipes of tending. Tended are the forest and its landscape, the natural fertility of the site, the stand in all its fine details of structures and functions, as well as the mutual relationship site - stand. Ecosystem tending belongs to the free style of silviculture. It is at the same time its most important foundation. Such forest tending leads to process-friendly forests which function with a remarkable natural automation because of the preserved virgin forest characteristics and its acquired economic and cultural value.

OUTLOOK

The big question is how to come from the virgin forest, but also from the technified forest, to the commercial forest patterned on nature. The mental turnaround based on knowledge gleaned from the virgin forest should not be hesitant. The practical execution, by contrast, can only be a process which is going to develop continuously and respects the local circumstances. The process of forest tending relations and automation, and as last consequence the self-tending of the forest, must be the ultimate endeavor. Self-tending may also be called indirect tending whereby the forest is going to meet by itself our goals without our help. Scientific development of the tending of the forest ecosystem will be one of our vital tasks in the future.

Things can be taken care of successfully if the distance to them has grown sufficiently large. We hope that the catastrophies affecting the

environment and the forest made us ready for the task of tending the forest ecosystem. The multidimensional virgin forest has been a teacher to us in its singularity. From this should result our philosophy and the ecosystem tending. That task continues to require sufficiently long experience and a gift for observation. Because clearcut and similar methods have destroyed existing experience, we are forced to continue to search for knowledge in the virgin forest, to overcome ourselves and to think differently in order to change from being an antiforester to being an ecoforester. The future forest management needs a new alphabet and a new technical dictionary derived from the virgin forest book. These we will have to write in the near future.

SUMMARY

Research results from the virgin forest require completely new concepts of forest management. The ecosystem mechanisms of the virgin forest should be respected in the future. This is undeniably possible together with simultaneous regard for economic demands. Virgin forest research confirms the validity of already existing silvicultural technologies which regard the forest as an ecosystem. Forest management patterned on nature is based on the principle of forest tending. Forest tending has developed into a leading system of forest treatment which has reached an ecological and economic level which never existed before. The international cooperation i virgin forest research, and especially in the transfer into forestry practice, promises much. International cooperation has never been so urgent a matter as today. All research disciplines within the field of forestry will have to acknowledge this fact.

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CURRENT KNOWLEDGE OF OLD GROWTH IN THE DOUGLAS-FIR REGION OF WESTERN NORTH AMERICA[1]

Thomas A. Spies

Research Forester
USDA Forest Service
Pacific Northwest Research Station
Corvallis, Oregon USA

FDC: 228.8: 180: (7-15)

SUMMARY

Old-growth forests in the Douglas-fir region of western North America have been the subject of considerable public debate and scientific research. Research efforts with regard to old-growth structure, function, habitat, dynamics and management are reviewed. New findings are revealing that old-growth structure varies widely across the region as a consequence of variation in disturbance and stand history. Most plant and animal species occur across the full range of stand development; however, several plant and animal species find optimum habitat in old-growth Douglas-fir stands. Different strategies are available for old-growth management on public lands.

Keywords: Forest development, structure, function

INTRODUCTION

Old-growth Douglas-fir forests once blanketed the mountains and valleys of many areas of the Douglas-fir Region of northwestern North America. Today much of this original forest condition is gone, for example, less than 20 % of the original area of old growth in western Washington and Oregon remains (Spies and Franklin 1988). The fate of the remaining stands is a subject of intense public debate at regional and national levels. Considerable research has been conducted in old-growth Douglas-fir forests in the last 20 years. Although many questions about the ecology of these forests remain, old-growth Douglas-fir is one of the most well-known old-growth types in the world.

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[1] Portions of this paper are adapted from Spies and Franklin (1988).

The objectives of this paper are to review the current state of knowledge of old-growth Douglas-fir forests in western Oregon and Washington in terms of their structure, function, composition, and dynamics. Management options will then be discussed.

STRUCTURE

Considerable research has focused on identification of the structural components of old-growth Douglas-fir forests. Franklin et al. (1981) identified four major structures of old growth forests: live old-growth trees; standing dead trees or snags; fallen trees or logs on land; and logs in streams.

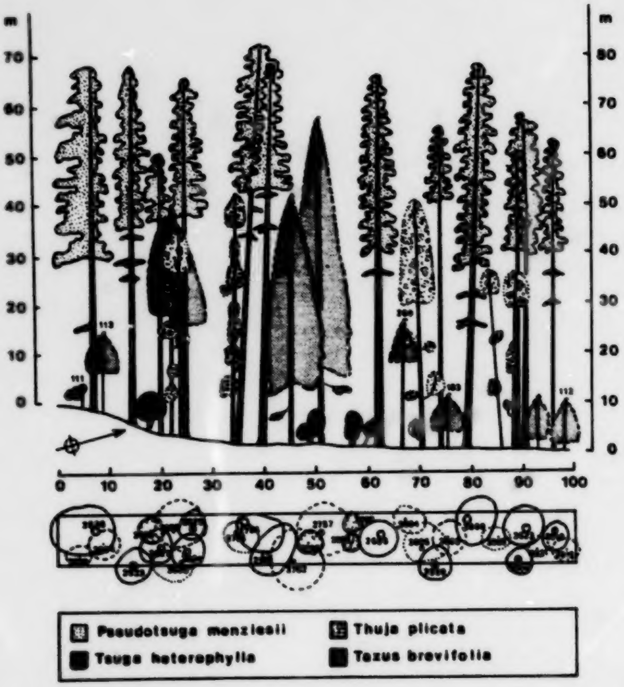

Figure 1. Vertical and horizontal structure of an old-growth Douglas-fir stand from the Oregon Cascade Range. (From Kuiper 1988)

Large old-growth Douglas-firs, and shade tolerant associates provide several unique habitat and functional roles. First, by

virtue of their great height (Figure 1), more than 70 meters in many stands, the volume of the old-growth ecosystem is large, resulting in a diversity of environments and habitats from the canopy to the forest floor. Consequently, habitat is provided for many organisms including epiphytic lichens and mosses that grow on fan-shaped branches, bats and birds that feed on insects or use the branches for nesting, and animals that dwell in the cool moist understories. Many of the large trees have broken tops and cavities that provide nest sites for bird species. When the large trees die they leave large canopy openings that provide light to the understory that is valuable to the growth of understory trees and maintenance of populations of understory shrubs and herbs. Shade-tolerant trees--such as western hemlock, western redcedar and Pacific silver fir--are typically smaller in size than the seral Douglas-firs which are canopy emergents (Figure 1).

When canopy trees die they produce snags, which are abundant in all stages of Douglas-fir stand development (Spies et al. 1988). Large snags, more than 50 cm diameter and 15 m tall are most abundant in the first few decades after wildfire and in the old-growth stage. These large dead trees are valuable to cavity-excavating birds such as the pileated woodpecker (Dryocopus pileatus). The underside of sloughing bark also provides habitat for at least twelve vertebrate species (Brown 1985).

When live or dead trees fall to the forest floor they continue to function as important components of the ecosystem. Large, well-decayed logs, which are particularly common in old-growth forests, provide habitat to 150 or more species of vertebrate organisms and many hundreds of species of invertebrates (Brown 1985, Harmon et al. 1986). Large decayed Douglas-fir logs also provide germination sites of western hemlock and other plant species (Harmon and Franklin 1989). In forest streams, logs become habitat to vertebrates and invertebrates, trapping organic matter and storing inorganic sediments (Harmon et al. 1986).

Although many of the major structural components of old-growth Douglas-fir forests have been known for some time, only recently has any extensive quantitative analysis been conducted. Spies and Franklin (In press) examined over 200 unmanaged Douglas-fir stands from young to old growth. Discriminant analysis was used to evaluate variation in three age classes, young (40 to 80 years), mature (80 to 195 years), and old growth (195 to 900 years). Analysis of separate discriminant models based on different stand attribute sets, revealed that models based on overstory characteristics such as tree density, density of large Douglas-firs, and models based on overstory, understory, woody debris and stand conditions variables were most successful in distinguishing the age classes. Canonical variates analysis also indicated that best separation of the age classes was achieved by overstory attributes and a set of combined attributes. Considerable variation occurred in structure among the age classes. The age classes represented portions of a continuous gradient of structural variation that was associated with age.

Old-growth stands from different geographical provinces and relative site moisture classes varied considerably in structure. Much of the variation was associated with variation in densities of shade tolerant species and understory vegetation characteristics. Variation in old-growth structure across the region indicated that low to moderate levels of fire during the life of the stands had an important influence on stand structure.

FUNCTION

Gross primary production, the radiant energy fixed by photosynthesis per unit area of land, is maintained at high levels in old-growth Douglas-fir stands (Grier and Logan 1977). Net primary production (NPP), which is the gross primary production minus losses through plant respiration, is as high in old growth as in young Douglas-fir stands, although the form is different. In young stands most of the NPP is in biomass increment, but in old-growth tree mortality and litterfall constitute almost all of the NPP (Grier and Logan 1977).

Net wood production of Douglas-fir forests reaches a maximum by ninety years and can stay high for another 100 years, depending on site conditions, before declining (McArdle 1961). In an analysis of a thirty-six year record of gross and net growth in old-growth Douglas-fir (Debell and Franklin 1987), gross wood-volume growth was relatively high, but it was balanced by high tree mortality (Table 1). Net growth was minimal, and total stand volume stayed about the same.

Table 1. Cubic volume, growth, and mortality in cubic meters per hectare (1947-1983) by species for a 450 year-old *Pseudotsuga menziesii*/*Tsuga heterophylla* stand in the Cascade Range of Washington. (Adapted from DeBell and Franklin 1987)

Species	Volume (1947)	Gross growth	Mortality	Net growth
Pseudotsuga menziesii	547.9	79.6	107.1	-27.5
Tsuga heterophylla	254.7	116.8	59.8	+57.0
Abies spp.	58.8	26.9	16.7	+10.2
Other species	68.6	13.0	33.5	-20.5
Total	930.0	236.3	217.1	+19.2
Per annum		6.6	6.0	+0.5

Cycling of materials, an important component of ecosystem function, has not been well-studied in old-growth Douglas-fir forests. In general, nutrient losses from old-growth stands appear to be low (Sollins et al. 1980), although they may not differ much from young stands once canopy closure occurs (Cole et al. 1967). Where fog and low clouds are common, water yields from old growth may be up to 30 percent higher than in clearcuts because more water condenses and precipitates from the tall canopies with large amounts of surface area (Harr 1982). The age at which young forests intercept substaintial amounts of fog is not known.

HABITAT

Plant species diversity is typically higher in old-growth stands relative to younger closed canopy stages (Schoonmaker and McKee 1988, Spies In press). The highest plant diversity, however, occurs in very young stands following fire or clearcutting. Most plant species surveyed by Spies (In press) do not show a preference for old growth. However, at least 25 to 30 plant species appear to be more abundant and frequent in old-growth stands. For example, Taxus brevifolia, an understory tree, Tiarella trifoliata var unifoliata, an herb, and Lobaria oregana, a foliose canopy lichen, were all strongly associated with old growth in a survey of 177 stands of different ages (Spies In press).

Habitat associations of vertebrates with old-growth forests has received considerable attention in recent years. The most well-known case of a vertebrate species associated with mature and old-growth forests is the northern spotted owl (Strix occidentalis) (Forsman et al. 1984). This medium-size owl uses older forests for nesting, roosting, and foraging for its primary prey species, northern flying squirrels (Glaucomys sabrinus) and woodrats (Neotoma spp.). Because of the cutting of its habitat, without replacement, the spotted owl is currently being considered for listing as an endangered species protected under the Federal Threatened and Endangered Species Law.

Spotted owls are not the only species whose occurrence is associated with old-growth forests. A recently completed study of habitat relationships of salamanders, nongame birds, and small mammals (Ruggiero et al. In press) has turned up at least eight other vertebrates that are closely associated with old-growth forests in at least some portions of their ranges. Some 40 other vertebrates were found to be relatively more abundant in old growth than in earlier successional stages.

Many of the vertebrate species associated with old growth use specific old-growth structures such as decayed large

logs, large dead standing trees or large live old tree crowns for hiding and breeding.

DYNAMICS

Coarse and fine scale disturbances have both played important roles in establishment, development, and destruction of old-growth Douglas-fir forests. Fire is the most frequent and widespread coarse-scale disturbance occurring at scales of 1 to > 10,000 ha. Recent research has demonstrated that the fire regime of the region is more complex than orginally thought. Initial research in Mount Rainier National Park in the Washington Cascades estimated fire return intervals of 400 to 500 years for large catastrophic fires (Hemstrom and Franklin 1982). More recent research in the central Oregon Cascades (Stewart 1986, Morrison and Swanson In press) paints a more complex picture that includes smaller, less severe, but more frequent fires. Morrison and Swanson (In press) found that fire return intervals varied between less than 100 years and over 150 years for fires of all intensities. Excluding low severity fires, the return intervals were over 200 years.

Currently several different scenarios of fire and forest development and succession are recognized for the region (Spies et al 1988, Morrison and Swanson In press). In one scenario, catastrophic fire kills all the trees in an old-growth stand, initiating establishment of Douglas-fir and some western hemlock seedlings. These stands develop for a long period without a subsequent stand-replacement fire, and develop old-growth structure around 150 to 250 years. Coarse woody debris follows a cycle of increase, decrease and increase over this 400 to 800 year period (Figure 2A).

In a second scenario, lower intensity fires kill only portions of the trees in a patchy manner. New tree establishment occurs in the burned patches, and the stand develops old-growth characteristics of various tree sizes and large dead trees sooner than it would in the first scenario. The cycle of woody debris does not reach the peaks and valleys of the first scenario (Figure 2B).

In a third scenario, fires recurr after the intial fire, and development of the forest is delayed. The repeat fires consume woody debris and delay the onset of old-growth conditions relative to the time since the initial fire. Woody debris cycles reach lower minimums in this scenario (Figure 2C).

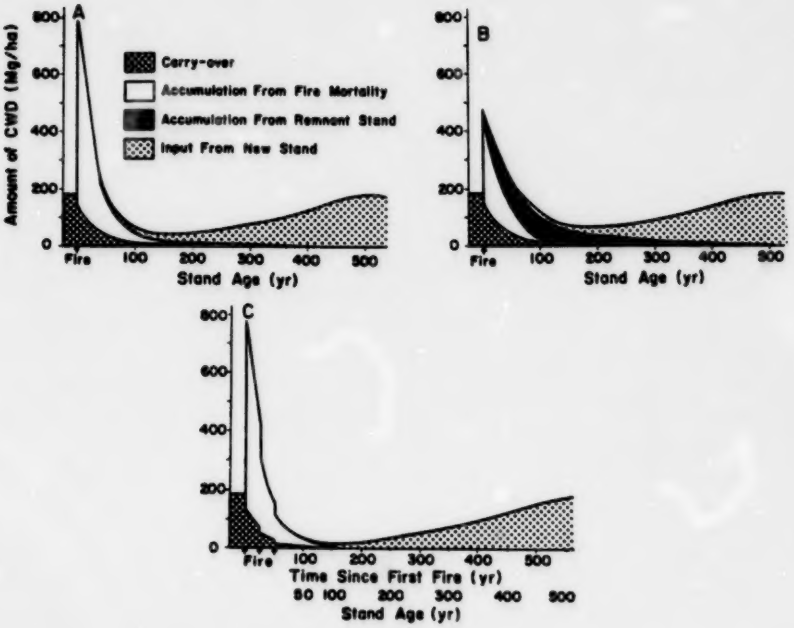

Figure 2. Predicted changes in coarse woody debris (CWD) mass following fire in a 450-yr-old <u>Pseudotsuga</u>-<u>Tsuga</u> forest: (A) catastrophic fire, (B) partial burn, (C)catastrophic fire and two subsequent fires 25 and 50 years later. CWD is divided into: present before the fire, produced by the fire, produced by the remnant stand, and produced by the stand growing after the fire (From Spies et al. 1988).

Several recent studies have identified that small-scale disturbances within old-growth stands are important to the dynamics of these forests. Franklin and Debell (1988) found that considerable mortality and replacement occurred over a 36-year period in 500 year old Douglas-fir/western hemlock forest. Annual rates of mortality were 0.75% but the mortality was balanced by recruitment of shade-tolerant tree species. Compositional changes were slow with exctinction of Douglas-fir predicted in 750 years at its current mortality rate. The importance of canopy openings to regeneration has been demonstrated by Stewart (1986) and Spies et al. (In press). Spies et al. (In press) found that gap formation rates were relatively low in old-growth Douglas-fir forests (0.2% of forest area per year), relative to other old-

growth forest types (Runkle 1985). However, gaps were the primary sites of hemlock recruitment to the canopy. Spies et al. (In press) also found that many gaps were slow to fill. They attributed the slow vegetative response to gaps to the type of mortality events that created the openings. Over 70% of the old-growth canopy trees die without disrupting the forest floor (Spies et al In press, Franklin and DeBell 1988).

MANAGEMENT

Old-growth forests are of increasing interest to the public and land management agencies. Recently the U.S.D.A. Forest Service issued a new policy that recognizes old-growth as a valuable component of the National Forests. Management of old growth requires several steps. First, a definition of old growth is required that translates the ecological concept into one that managers can use in inventory, planning, and silviculture. Second, an inventory and map of current old-growth acreage is needed for each land ownership. Third, management alternatives need to be developed in terms of silvicultural systems that will maintain and create old-growth conditions at stand and landscape scales.

The first of these activities has been addressed through the development of interim definitions for old-growth Douglas-fir and mixed-conifer forests (Old-growth Task Group 1986). These definitions provide minimum standards for old-growth Douglas-fir stands in terms of structural features that can be measured in on-the-ground inventories.

While definitions are needed to answer questions about how much old growth exists and where it is located, such definitions must rely on somewhat arbitrary minimums that are used in classifying a stand as old growth or not. Many stands exhibit old-growth character but may lack a certain density of snags or large trees that would exclude them from the old-growth class. For broader management objectives such as wildlife habitat and biological diversity, such definitions will not be suitable. An index of structural diversity might be more appropriate (Spies and Franklin 1988) because it enables stands of all ages and management history to be characterized on the basis of how much they resemble some idealized old-growth reference point. Examples of some indices for old-growth Douglas-fir have been developed (Franklin and Spies In press).

Traditional U.S. Forest Service inventories have been based on timber objectives and consequently used tree size as a primary variable. Elements of old-growth structure, such as number of canopy layers and coarse woody debris, require additional information that has not typically been collected. In addition, many of the questions about old-growth habitat function require

information about stand size and landscape context. Consequently, old-growth inventories must include maps. In the Douglas-fir region current inventory efforts are relying on LANDSAT imagery to map potential old-growth areas, and ground plots to evaluate attributes, such as woody debris, that can't be measured from remote sensing data. Current research efforts are focusing on how well canopy structure can be estimated from satellite imagery.

Current ideas of old-growth management span a range of activities from setting up old-growth reserves, to recreating old-growth characteristics on long rotations, to providing for individual structural components in young managed stands (Franklin et al. 1981). It is likely that all of these options will be exercised on public lands. However, the balance between them on a landscape scale is yet to be determined. Old-growth reserves are likely to be set up to provide habitat for the spotted owl. These reserves may be arrayed in a fashion that links them together with habitat corridors to facilitate owl movement between reserves.

Outside of old-growth reserve areas, management objectives on some lands may be to manage forests on long rotations (150 to 300 years) and to silviculturally manipulate young stands to reduce the time required to develop old-growth characteristics. Newton and Cole (1988) found that thinnings in young stands could shorten the time it takes to develop some old-growth characteristics such as large trees.

On some lands the objective might be to retain some old-growth structures in managed plantations to improve their habitat suitability. Under intensive forest management woody debris levels will be only a small fraction of that found in unmanaged stands (Spies and Cline 1988). Some large woody debris could be retained in managed forests by leaving large live trees and snags when old-growth stands are harvested. The retention and development of structural diversity in managed forests is a central focus of a call for new perspectives in forest management (Franklin 1989). Research on old-growth Douglas-fir ecosystems in the last 15 years has lead to a new appreciation of ecological diversity and is having a major influence on the direction that forest management will take in the Douglas-fir region.

CONCLUSIONS

Recent research has revealed that old-growth Douglas-fir forests are complex ecosystems that provide lessons for forest management. They are structurally distinct from younger forest stages, although many of the structural components survive natural disturbances and can be found in young stands. In many respects old-growth function and composition are similar to younger, unmanaged stands. However, old growth does represent a compositionally and functionally unique condition for several

characteristics. Disturbance at coarse and fine scales has played an important role in the development and structure of old-growth Douglas-fir forests. Old growth is now recognized as a desirable management objective for many public lands in the region. The structure and dynamics of unmanaged Douglas-fir forests is providing new models for forest management at stand and landscape scales.

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S U K Z E S S I O N S T Y P E N V O N W A L D Ö K O S Y S T E M E N D E R G E M Ä ß I G T E N U N D D E R B O R E A L E N Z O N E

Harald Thomasius
Professor
Sektion Forstwirtschaft Tharandt
Technische Universität Dresden, DDR

FDC: 182.2: (212)

Zusammenfassung

Die spezifische Sukzession der verschiedenen Waldgesellschaften gemäßigter und höherer Breiten ergibt sich aus der ökologischen Situation des Standortes, dem Diasporenangebot nischenkonformer Pflanzen sowie der Ontogenese und Biomasse-Akkumulationsfähigkeit dieser Pflanzen. Auf solchen Gesetzmäßigkeiten aufbauend wurde ein System der Sukzessionstypen ausgearbeitet, in dem autochthone und allochthone Sukzessionen unterschieden werden. Die autochthonen werden weiter in solche mit konvergierender und divergierender Stoffbilanz sowie verschiedene Formen des Baumartenwechsels im Laufe der Sukzession unterschieden.

Schlüsselwörter: Baumartenwechsel, Biomasseakkumulation, Diversität, Gleichgewicht, Intermediärbaumart, Klimax, Klimaxbaumart, Lebensform, Nische, Ontogenese, Paludifikation, Pionierbaumart, Stabilität, Staedy state, Stoffbilanz, Sukzession, autogen, allogen, Sukzessionstypen, Taiga, Tundra, Wachstumsstrategie, Waldgesellschaften, Waldökosysteme

1. Einleitung

So wie es verschiedene natürliche Waldgesellschaften bzw. Waldökosysteme gibt, gibt es auch verschiedene zu ihnen hinführende Sukzessionen. Trotz dieser Vielfalt kann man bestimmte Gesetzmäßigkeiten der Sukzession erkennen und darauf aufbauend eine Gliederung der Sukzessionstypen vornehmen.

Für die Sukzession von Waldökosystemen sind maßgeblich:

1. Die ökologischen Gegebenheiten auf der betreffenden Fläche sowie deren interne und externe Modifikation
2. Das Diasporendargebot nischenkonformer Pflanzen
3. Die Ontogenese und Akkumulationsfähigkeit der nischenkonformen Pflanzen.

Daneben können außergewöhnliche Ereignisse, wie Feuer, Sturm, Schnee u. a. Faktoren, eine wesentliche Rolle spielen.

Auf diesen Prinzipien aufbauend wurde eine Gliederung der Sukzessionstypen ausgearbeitet.

2. Wesentliche Einflußgrößen

2.1. Die ökologischen Gegebenheiten

Richtgröße der Sukzession sind Umweltfaktoren, die in ihrer Gesamtheit den Standort bilden. Dieser wird durch die ökologischen Koordinaten x_1, x_2, x_3 charakterisiert und durch die Koordinatendistanzen Δx_1, Δx_2, Δx_3 als Nische abgegrenzt (Abb. 1).

Wesentlich für die Sukzession ist nun

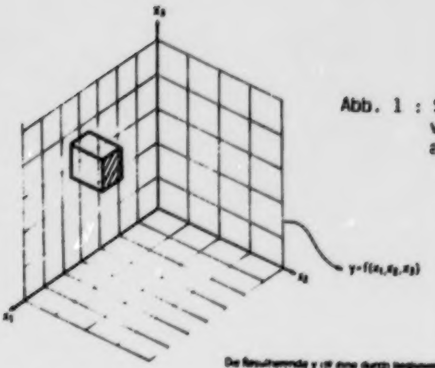
a) die Lage des Standortes im ökologischen Raum

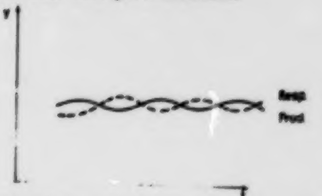
b) die Konstanz bzw. Varianz der ökologischen Koordinaten.

Vom Standort generell (Klima und Boden) sind Artenspektrum, Diversitätspotenz (biozönotisches Grundgesetz) und seine Produktivität abhängig. Daraus ergibt sich die bekannte Waldtypengliederung nach der Nährstoffausstattung und dem Feuchtigkeitsangebot mit den zu ihnen führenden Sukzessionen.

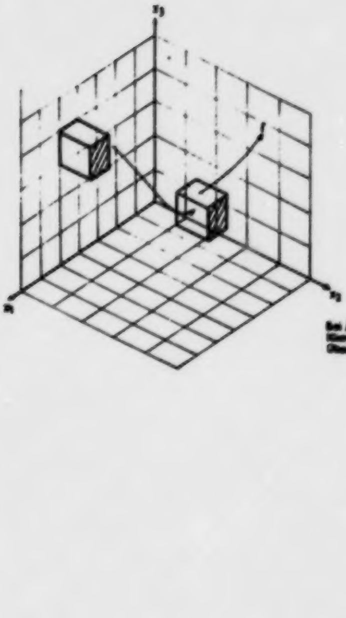
Neben dem Einfluß des Standortes auf die Primärproduzenten, besonders die Bäume, ist auch dessen Wirkung auf die Destruenten bedeutungsvoll, weil davon u. a. abhängt, ob sich im Verlauf der Sukzession ein Gleichgewichtszustand zwischen Stoffaufbau und -abbau einstellen kann. Ist das nicht der Fall, so kommt es entweder zu einem verstärkten Stoffabbau oder zur Ansammlung von Nekromasse. Letzteres ist z. B. bei einer Paludifikation unter thermisch und aerisch ungünstigen Bedingungen der Fall.

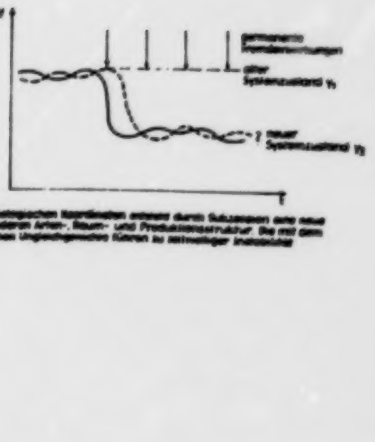
Abb. 1 : Schematische Darstellung des Einflußes von Nischenkonstanz und Nischenvariation auf den Ökosystemzustand





Die Resultierende y ist eine durch bestimmte Arten-, Raum- und Produktionsstrukturen gekennzeichnete und eine bestimmte Stabilität besitzende Klimax.





Bei Änderung der ökologischen Koordinaten entsteht durch Sukzession eine neue Klimax mit einer anderen Arten-, Raum- und Produktionsstruktur. Die mit dem Übergang verbundenen Ungleichgewichte führen zu zeitweiliger Instabilität.

Neben der Naturausstattung des Standortes ist es wichtig, ob dieser eine konstante oder variable Größe darstellt. Dementsprechend ist zwischen autochthonen und allochthonen Sukzessionen zu unterscheiden. Bei ersteren wird unterstellt, daß die Umweltfaktoren (extern) gleichbleibend sind, während sie sich bei letzteren (extern und intern) wandeln, wie es z. B. bei Fremdstoffeinträgen, Grundwasserspiegeländerungen, Temperaturerhöhungen usw. der Fall ist (Abb. 1).

Bei waldkundlichen und forstwissenschaftlichen Untersuchungen wurde bislang i. d. R. Konstanz der Umweltbedingungen unterstellt. Das mag in früherer Zeit und bei vielen Fragestellungen berechtigt gewesen sein. Trotzdem muß man sich darüber im klaren sein, daß diese Bedingung zu keiner Zeit streng erfüllt gewesen ist. Man denke nur an die bekannten Klimaveränderungen im Verlauf geologischer Zeiträume mit den sich daraus ergebenden Konsequenzen für die Vegetation (z. B. postglaziale Waldentwicklung). Angesichts der in jüngster Zeit eingetretenen dramatischen Umweltveränderungen wird das Konzept der autochthonen Sukzession immer problematischer.

2.2. Das Diasporendargebot nischenkonformer Pflanzen

Für die Erstbesiedlung (Primärsukzession) oder Wiederbesiedlung (Sekundärsukzession) einer Fläche und die weitere Dynamik des sich entwickelnden Ökosystems ist das Vorhandensein von Diasporen standorttauglicher Pflanzenarten entscheidend. Dabei muß "standortstauglich" dynamisch, d. h. in Verbindung mit den verschiedenen internen und externen Umweltmodifikationen, aufgefaßt werden.

Bei Sekundärsukzessionen, mit denen es der Forstmann überwiegend zu tun hat, muß außerdem zwischen Immigranten aus der Umgebung (Samen) und Residuenten (Samen und regenerationsfähige Pflanzenteile vom Vorbestand) unterschieden werden. Letztere können die Initialstadien der Sukzession entscheidend beeinflussen (Abschn. 3.2.).

2.3. Ontogenese und Akkumulationsfähigkeit nischenkonformer Pflanzen

2.3.1. Allgemeines

Für die Wettbewerbsfähigkeit der Pflanzen und den Wechsel der Artenstruktur im Verlauf der Sukzession sind die Ontogenese und Biomasse-Akkumulationsfähigkeit der beteiligten Spezies überaus bedeutungsvoll. Wesentlich sind dabei:

a) Die genetisch geprägte Lebenserwartung

b) Die Wachstumsstrategie, insbesondere der Zuwachsgang im Laufe des Jahres (saisonales Wachstum) und des gesamten Lebens (biozyklisches Wachstum)

c) Die mit der Lebensform und Wachstumsstrategie korrespondierende Fähigkeit und Art, Biomasse zu akkumulieren

d) Das Vermehrungspotential sowie die Ausbreitungs- und Migrationsfähigkeit der verschiedenen Spezies.

2.3.2. Ontogenese, Akkumulations- und Konkurrenzfähigkeit verschiedener Lebensformen

Bei der Entwicklung von Waldökosystemen, die zugleich mit einer autogenen Wandlung der Umweltbedingungen verbunden ist, ändert sich gesetzmäßig das Spektrum der vorkommenden Lebensformen (Abb. 2):

1. Annuelle

   Im Initialstadium der Waldsukzession treten vor allem heliophile Annuelle auf, weil sie eine große Ausbreitungspotenz besitzen und nahezu "allgegenwärtig" sind. Diese Pflanzen durchlaufen in einem Jahr ihren gesamten Lebenszyklus und besitzen eine große Biomasseproduktion. Diesem Sukzessionsvorteil steht der Nachteil fehlender Akkumulationsfähigkeit gegenüber.

2. Bienne

   Das Leben dieser Pflanzen vollzieht sich in 2 Jahren (z. B. Digitalis). Im Jahr der Keimung entstehen sterile Pflanzen, deren Biomasseproduktion im Spätsommer kulminiert. Ein Teil davon (Wurzelstock und Blattrosette) überdauert den Winter. Daraus entsteht dann im 2. Jahr eine fertile Pflanze, deren Biomasseproduktion im Frühsommer kulminiert. Im Spätsommer erfolgt die Fruktifikation. Dank dieser Ontogenese sind die Biennen im 2. Jahr den Annuellen überlegen.

3. Perennierende Gräser und Kräuter

   Bei diesen Pflanzen ist die Biomasseproduktion im Jahr der Keimung - im Vergleich zu den Annuellen - noch bescheiden. Andererseits sind perennierende Gräser und Kräuter in der Lage, einen erheblichen Teil der produzierten Biomasse hypogäisch zu akkumulieren. Aus den unterirdischen Pflanzenteilen bildet sich dann in den folgenden Jahren ein oft flächendeckender Pflanzenbestand mit großer Biomasseproduktion und meist auch Fruktifikation. Daraus folgt, daß die Perennen bei generativer Vermehrung anfangs den Annuellen und Biennen nachstehen. Später kehrt sich dann die Wettbewerbsfähigkeit um, weil die Perennen nun ein höheres Akkumulationsniveau, eine größere Bestandesdichte, oft auch eine größere Wuchshöhe und damit eine stärkere Konkurrenzfähigkeit erlangen.

4. Sträucher

Bei generativer Vermehrung ist die Biomasseproduktion der Sträucher in den ersten Jahren noch ziemlich gering. Sie sind darum in der Initialphase der Sukzession meist den Kräutern und Gräsern unterlegen. Das ändert sich nach Eintritt in die Auxophase, die durch starke Biomasseproduktion und -akkumulation charakterisiert wird. In diesem Lebensabschnitt können auch Sträucher geschlossene Bestände bilden und die vorher dominierenden Kräuter und Gräser zurückdrängen. Bei gleichzeitiger Ansiedlung von Bäumen sind sie allerdings den noch wesentlich langlebigeren und akkumulationsfähigeren Bäumen unterlegen.

5. Bäume

Die den Charakter des Waldes bestimmenden Bäume lassen sich nach sukzessionsökologischen und -ontologischen Gesichtspunkten in Pionier-, Intermediär- und Klimaxbaumarten einteilen.

- Pionierbaumarten

  Das sind permanent heliophile Spezies mit einer für Bäume relativ rasch ablaufenden Ontogenese, d. h. früher Zuwachskulmination, zeitigem Eintritt der Fertilität, kurzer Lebensdauer und relativ geringer Akkumulationsfähigkeit. Sie fruktifizieren oft und reichlich und besitzen ein großes Ausbreitungspotential. Wegen ihres in allen ontogenetischen Stadien hohen Lichtbedarfs (Abb. 3) können sich die Pionierbaumarten im großen nur auf ausgedehnten Freiflächen verjüngen und behaupten. Ihre rasche Ontogenese verschafft ihnen gegenüber Intermediär- und Klimaxbaumarten anfangs Vorteile. Auf günstigen Standorten werden sie jedoch im Zuge der Sukzession von langlebigeren und akkumulationsstärkeren Intermediär- und Klimaxbaumarten abgelöst.

- Intermediärbaumarten

  Die dieser Baumartengruppe zugeordneten Spezies zeichnen sich in der Jugend noch durch Schattentoleranz aus, haben aber im fortgeschrittenen Alter ein größeres Lichtbedürfnis. Dank dieser variablen Lichtökonomie können sie sich auch unter dem lichten Kronenschirm oder in Bestandeslücken gut verjüngen. Mit fortschreitendem Alter und steigendem Lichtbedarf muß dieser Schirm dann verschwinden, was bei kurzlebigen Pionierbaumarten auch der Fall ist.

- Klimaxbaumarten

  Die Angehörigen dieser Kategorie sind permanent schattentolerant und durchlaufen eine langsame Ontogenese, die durch gedämpftes Jugendwachstum, späte Zuwachskulmination, späten Eintritt der Fertilität, größere Lebensdauer und hohe Akkumulationsfähigkeit gekennzeichnet ist. Die im Verhältnis zu Pionier- und Intermediärbaumarten weniger

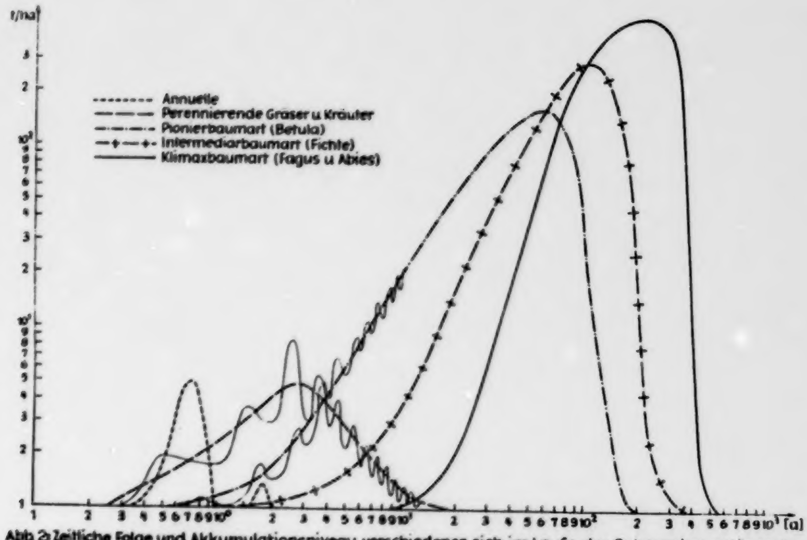


Abb. 2: Zeitliche Folge und Akkumulationsniveau verschiedener, sich im Laufe der Sukzession ablösender Lebensformen (IRRGANG 1988)

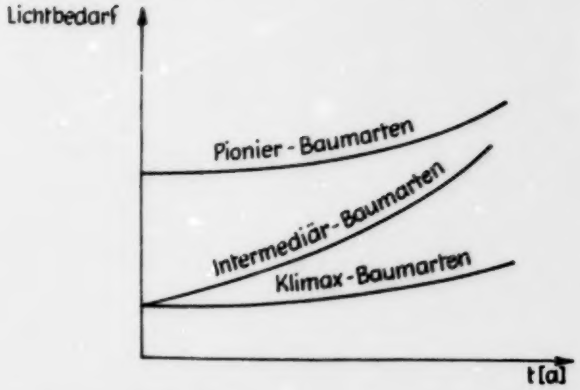


Abb. 3: Lichtbedarf bzw. Schattentoleranz von Pionier-, Intermediär- und Klimax - Baumarten

häufige und weniger reichliche Fruktifikation sowie die besonders bei schwersamigen und zoochoren Spezies weitaus geringere Ausbreitungsfähigkeit läßt kaum eine rasche Besiedlung größerer Freiflächen zu. Hinzu kommt eine wesentlich geringere ökologische Amplitude dieser Baumarten. Dem Nachteil einer langsamen Ontogenese und eines geringen Jugendwachstums der Klimaxbaumarten steht der Vorteil großer Schattentoleranz und Akkumulationsfähigkeit gegenüber. Diese Eigenschaften haben zur Folge, daß Klimaxbaumarten dort, wo sie ein gutes Gedeihen haben, letztendlich in jahrhundertelangem Konkurrenzkampf als Sieger hervorgehen. Diese sich aus einem langfristigen Wettbewerbsvorteil ergebende "Macht" wird jedoch eingeengt durch die im Vergleich zu den Intermediär- und Pionierbaumarten weitaus geringere ökologische Potenz.

Weitere Details zu diesen ontogenetischen Baumartengruppen enthält Tabelle 1. Aus sukzessionsökologischer Sicht ist vor allem die Einengung der ökologischen Amplitude von den Pionier- über die Intermediär- zu den Klimaxbaumarten bedeutungsvoll (Abb. 4).

3. Sukzessionstypen natürlicher Waldökosysteme und deren systematische Ordnung

3.1. Allgemeines

Bei der nachfolgenden Typisierung und Systematisierung werden als Ordnungsprinzipien benutzt:

1. Die Konstanz bzw. Varianz der Umweltbedingungen (Differenzierung in autogene und allogene Sukzessionen)
2. Die Konvergenz bzw. Divergenz der Stoff- und Energiebilanz bei fortschreitender Sukzession (Existenz und Absenz eines balancierten Schlußwaldstadiums)
3. Das ökologische Niveau des Standortes und damit die Dominanz bestimmter ontogenetischer Baumartengruppen in den höheren Sukzessionsstadien (Pionier-, Intermediär- oder Klimaxbaumarten).

Schließlich ist noch zu berücksichtigen, ob sich die Initialstadien überwiegend aus immigrierten Diasporen oder vegetativ regenerierenden Residenten (Rhizomen, Stolonen, Wurzeln und Stöcke) entwickeln.

Zur Veranschaulichung dieser vielgestaltigen Prozesse und im Interesse der Formalisierbarkeit wurde das auf Abbildung 5 dargestellte Schema entworfen.

Tab. 1 Klassifikation der Baumarten nach sukzessionsökologischen Merkmalen, die für die Fichten-Sukzession bedeutungsvoll sind

Merkmal-Kategorien	Sukzessionsorientierte Lebensformen von Bäumen[1]		
	Pionierbaumarten	Intermediärbaumarten	Klimaxbaumarten
Ökologie			
- Licht (Abb. 3)	in allen Entwicklungsstadien großer Bedarf, permanente Lichtbaumarten	in den ersten Entwicklungsstadien Schattentoleranz, später höherer Lichtbedarf, temporäre Lichtbaumarten	in allen Entwicklungsstadien große Schattentoleranz, permanente Schattenbaumarten
- Resistenz gegenüber meteorologischen Extremen auf der Freifläche (Frost, Hitze, Nässe, Trockenheit)	sehr ausgeprägt	intermediär	sehr gering
- Standortsamplitude	breit oder Spezialisierung auf Extremstandorte, Pionierbaumarten insgesamt sämtliche Waldstandorte einnehmend	mittel, auf Extremstandorten nur begrenzt oder nicht mehr auftretend	schmal, im Prinzip nur trophisch und hygrisch günstige Standorte einnehmend
Ontogenese			
- Wachstum	rasches Jugendwachstum, frühe Kulmination des laufenden Zuwachses, rascher Zuwachsrückgang nach der Kulmination; relativ niedrige Akkumulationsfähigkeit (maximale Wachstumsgröße relativ klein)	bezüglich Jugendwachstum, Kulminationszeitpunkt des Zuwachses, Zuwachsrückgang nach der Kulmination und maximaler Wachstumsgröße zwischen Pionier- und Klimaxbaumarten stehend	langsames Jugendwachstum späte Kulminationen des laufenden Zuwachses, lang anhaltender Zuwachs nach der Kulmination, große Akkumulationsfähigkeit und somit große Endwerte
- Lebensdauer	kurz, 10^2 bis 2.10^2 a	mittel, etwa 2.10^2 bis 5.10^2 a	lang, meist $> 5.10^2$ a

1) Die hier benutzten Bezeichnungen Pionier-, Intermediär- und Klimaxbaumarten sind nicht ganz korrekt, weil auch Pionier- und Intermediärbaumarten eine Klimax sowie Intermediärbaumarten unter günstigen Bedingungen das Erstwaldstadium bilden können (Abschn. 2.1.5.1.). Wegen des Fehlens besserer Termini wurden die bisher gebräuchlichen beibehalten.

3.2. Systematik der Sukzessionstypen

1. Autogene Sukzessionen

Diese Kategorie umfaßt Sukzessionen, die unter weitgehend gleichbleibenden äußeren Umweltbedingungen ablaufen. Trotz dieser Voraussetzung muß die Stoff- und Energiebilanz nicht in jedem Fall mit fortschreitender Sukzession gegen Null konvergieren (steady state). Eine solche Divergenz tritt auf, wenn der Stoffabbau als Folge ungünstiger Umweltbedingungen gehemmt ist, so daß es bei permanentem Ungleichgewicht zu fortschreitenden Akkumulationen kommt. Dementsprechend müssen 2 Fälle unterschieden werden.

1.1. Autogene Sukzessionen mit gegen Null konvergierender Stoffbilanz

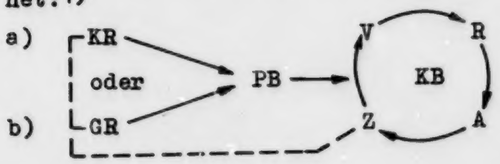
Unter gleichbleibenden und ökologisch günstigen Umweltbedingungen stellt sich nach Passage verschiedener, noch unbalancierter Sukzessionsstadien ein dynamischer Gleichgewichtszustand zwischen Stoff- und Energieinput sowie Stoff- und Energieoutput ein. Verbunden damit ist eine bestimmte Arten-, Raum- und Altersstruktur. Als Resultierende dessen ist ein Höchstmaß an Stabilität gegenüber solchen Faktoren zu erwarten, die während der Sukzession wirkten und eine Adaptation hervorgerufen haben.

Damit im Zusammenhang sei bemerkt, daß von einer Klimax im eigentlichen Sinne des Wortes nur gesprochen werden kann, wenn sich quasi als Abschluß einer Entwicklung ein durch Nullbilanz charakterisiertes und bei gleichbleibenden Umweltbedingungen theoretisch unbegrenzt existenzfähiges Schlußwaldstadium einstellt.

Die zu einem solchen steady state führende Sukzession kann, je nach Standort und Ontogenese der daran beteiligten Baumarten, auf dreierlei Art verlaufen.

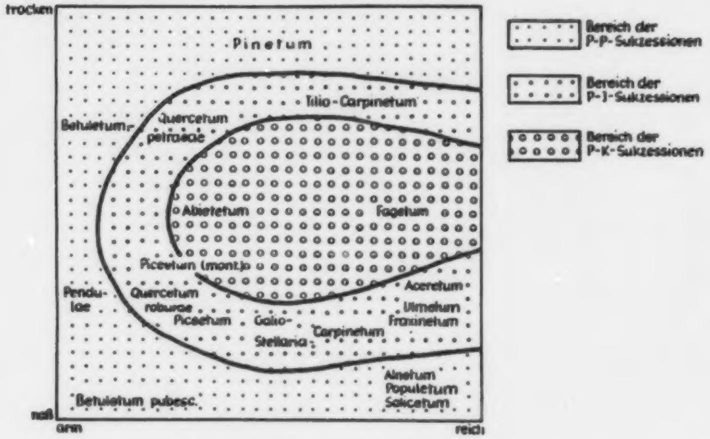
1.1.1. P-K-Sukzession

Dieser Sukzessionstyp wird durch folgende Sequenz gekennzeichnet:[1]



1) Erläuterung der Abkürzungen auf Abbildung 5

Abb. 4: Ökologische Bereiche der verschiedenen Sukzessionstypen und dazugehörige Waldgesellschaften



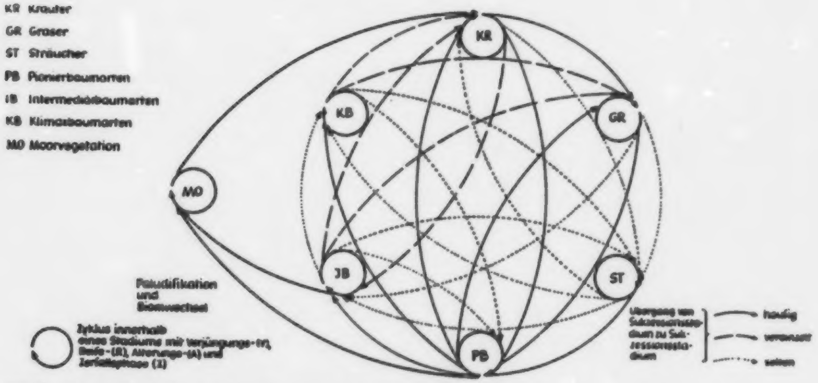


Abb. 5: Schematische Darstellung der durch Dominanz bestimmter Lebensformen gekennzeichneter Sukzessionsgradien von Waldökosystemen und ihrer Sequenzen

Dabei sind im Initialstadium 2 Varianten möglich:

a) Die Sukzession beginnt mit einem sich gut ausbildenden Kräuterstadium, von dem die Sukzession direkt zum Pionier- oder Anfangswaldstadium führt. Das trifft dort zu, wo bei einem gut geschlossenen Vorbestand nach plötzlicher Freilage (Naturkatastrophe, Waldbrand, Kahlschlag) genügend Freiraum für die Ansiedlung von Annuellen, Biennen oder auch perennierenden Kräutern vorhanden ist, die eine gut zersetzbare Streu liefern. Gleichzeitig stellen sich meist auch Keimlinge von Pionierbaumarten ein, die aber noch völlig untergeordnet sind.
Nach anfänglicher Flächendeckung durch Annuelle und Bienne setzen sich bald (nach 3 bis 5 Jahren) die Pionierbaumarten durch und bilden einen Anfangswald.
In diesem entscheidend von der Ausgangssituation abhängigen Fall kommt es nicht oder nur andeutungsweise zu einem Grasstadium. Das schließt natürlich nicht aus, daß sich auch Gramineen unter dem Schirm des heranwachsenden Anfangswaldes ansiedeln und erhalten. Sie werden aber nicht dominant und bleiben meist steril.

b) In aufgelichteten Vorbeständen haben sich bereits vor der Zerstörung Lichtgräser angesiedelt, die danach bald dominieren, eine mehr oder minder geschlossene Rasendecke bilden und fruktifizieren. Die Ausbildung eines Kräuterstadiums wird dadurch verhindert oder stark eingeengt.

Im Gegensatz zu dem unter a) beschriebenen Fall halten sich solche Grasdecken häufig ziemlich lange, weil Gehölze erst dann Fuß fassen können, wenn als Folge intraspezifischer Konkurrenz (Selbstverdämmung) oder Seneszens Lücken im Grasfilz entstehen.

Nach Überwindung des Kraut- und/oder Gräserstadiums entwickeln sich die Pioniergehölze zu einem mehr oder weniger dicht geschlossenen Anfangswald, der rasch heranwächst und Dendromasse akkumuliert. Als Gattungen sind daran Betula, Sorbus, Populus und Salix beteiligt. In der mit etwa 70 bis 80 Jahren einsetzenden Alterungsphase wandern dann Klimaxbaumarten ein[1] und lösen nach und nach die Pionierbaumarten ab.

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[1] Die Überlagerung von Pionier- und Klimaxbaumstadium wird von zahlreichen Waldökologen als Zwischenwaldstadium bezeichnet. Solche Stadienüberlagerungen sind natürlich auch in allen anderen Fällen gegeben.

Nach dem Verschwinden der Pionierbaumarten bilden die Klimaxbaumarten eine durch steigende Dendromasseakkumulation gekennzeichnete Aufbauphase, die schließlich zum Schlußwald führt. Dieser unterliegt bei zeitlichem Nacheinander und später auch räumlichem Nebeneinander von Verjüngungs- (V), Reife- (R)[1], Alterungs- (A) und Zerfallsphase (Z) einem internen (kleinen) Zyklus, der nach BORMAN und LIKENS (1980) treffend als shifting mosaik steady state bezeichnet wird. Dabei können auch Sciophyten verschiedener Lebensformen, vor allem verjüngungshemmende Moose (KARPOV 1983) oder verjüngungsfördernde Baumleichen mannigfaltige Modifikationen hervorrufen.

Schließlich kann es auch innerhalb des Schlußwaldstadiums als Folge wechselnder Lichtverhältnisse, autogener Standortsmodifikationen oder allelopathischer Wirkungen zu einem Wechsel der Klimaxbaumarten von Generation zu Generation kommen, wie vor allem von sowjetischen Waldökologen häufig berichtet wird (MOROSOW 1928 u. a.).

Der hier beschriebene Sukzessionstyp ist charakteristisch für Bergmischwälder der temperaten Zone, in denen Buche, Tanne u. a. Klimaxbaumarten das Schlußwaldstadium bilden und auch die Fichte als Mischbaumart vertreten ist. Im pflanzensoziologischen Sinne handelt es sich dabei überwiegend um Abieti-Fageten und diesen nahestehende Gesellschaften (Aceri-Fageten, Abieteten).

Diese Wälder besitzen im Schlußwaldstadium ein relativ kleinflächiges Mosaik verschiedener Entwicklungsphasen (V, R, A, Z) und während der Zerfalls- und Verjüngungsphase eine plenterartige Struktur. In der Reife- und Altersphase kann es zu weitgehendem Gleichschluß kommen, wenn zwischen dem Abschluß des Höhenwachstums und dem physischen Alterstod der Bäume eine größere Zeitspanne liegt, so daß auch "jüngere" Bäume zum oberen Kronendach aufschließen können (KORPEL 1978).

Dank ihrer Artenmannigfaltigkeit und Ungleichaltrigkeit zeichnen sich die aus P-K-Sukzession hervorgegangenen Schlußwälder durch eine verhältnismäßig große Stabilität gegenüber Sturm, Schnee und Insekten aus, d. h. gegenüber solchen Faktoren, die schon während der Sukzession wirkten und an die eine Adaptation erfolgt ist. Bei außergewöhnlichen Belastungen durch solche Faktoren kommt es nur zu partiellen Schäden, die bald überwunden werden. In diesen Fällen werden i. d. R. nur die Proportionen zwischen den einzelnen Phasen des Schlußwaldes verändert, das System als Ganzes wird jedoch nicht zerstört.

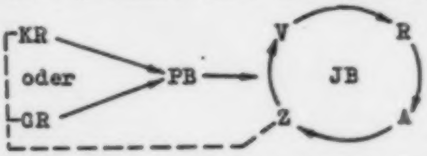
---

1) Es wird hier bewußt von Reife- statt Optimalphase gesprochen, da "optimal" eine anthropozentrische Wertung darstellt.

Eine völlige Destruktion kommt wohl nur bei sehr extremen Waldbränden zustande. Die größte Disposition dafür ist in der Alters- und Zerfallsphase vorhanden, weil hier der Vorrat trockener, leicht entzündbarer und gut brennbarer Substanzen am größten ist. Nach solchen Katastrophen beginnt dann der gesamte Zyklus (großer Kreislauf) wieder von vorn.

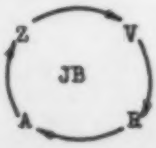
1.1.2. P-J-Sukzession

Dort, wo die eigentlichen Klimaxbaumarten aus ökologischen oder migratorischen Gründen weitgehend fehlen, so z. B. in der orealen Stufe der Gebirge gemäßigter Breiten und auf verschiedenartigen, nicht extremen Standorten der borealen Nadelwaldzone, vollzieht sich die Sukzession ähnlich wie bei 1.1.1., nur daß hier das Schlußwaldstadium von Fichten oder anderen Intermediärbaumarten gebildet wird. In diesem Falle gilt die Sequenz



Da dieser Sukzessionstyp bei einer weitaus größeren Standortspalette auftritt, kommt es zu einer stärkeren Differenzierung der den Anfangswald bildenden Pionierbaumarten. Auf trophisch günstigeren Standorten oder bei einem zeitweilig größeren Nährstoffangebot aus Asche nach Waldbränden treten im frischen und feuchten Bereich Pappel-, Weiden- oder Erlenarten (s. o.) und im trockneren die Eberesche auf. Auf armen Standorten sind es besonders Birken- und Kiefernarten, wobei ein Vikarismus zwischen trockenen Standorten (z. B. Sandbirke) und feuchten Standorten (z. B. Moorbirke) zu beobachten ist (WALTER u. BRECKLE 1986).

Diese Pionierwälder werden dann nach Eintritt in die Alterungsphase (70 bis 100 Jahre) Schritt für Schritt von Fichten oder anderen Intermediärbaumarten unterwandert und allmählich abgelöst. Innerhalb des sich nun entwickelnden Intermediärbaumarten-Schlußwaldes vollzieht sich wiederum der kleine Kreislauf



im Sinne eines shifting mosaik steady state. Die diese einzelnen Phasen repräsentierenden Mosaikflächen sind jedoch wesentlich größer (sog. Makromosaik n. KRAUKLIS 1975) und die Rotationszeit ist wesentlich kürzer als bei der P-K-Sukzession.

Auf Grund der Artenarmut, der weitaus einfacheren Raum- und Altersstruktur sowie der schwächeren Vernetzung von Rückkopplungsmechanismen sind die Schlußwälder einer P-J-Sukzession gegenüber Sturm, Schnee, Insekten und Feuer weniger stabil als die einer P-K-Sukzession. Aus diesem Grunde kommt es hier häufiger zu größeren Waldzerstörungen durch Naturkatastrophen, wozu wiederum die Alters- und Zerfallsphase am stärksten prädestiniert sind.

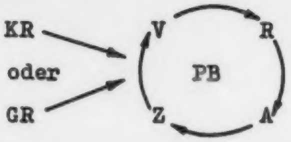
An dieser Stelle sei vermerkt, daß die breitere ökologische Amplitude der Intermediärbaumarten eine unmittelbare Verjüngung auf der Freifläche, d. h. ohne ein Pionierbaumstadium, nicht ausschließt.

Selbstverständlich ist auch im Intermediärbaum-Schlußwald ein Baumartenwechsel möglich.

Die meisten Fichtenwaldgesellschaften sind das Resultat von P-J-Sukzessionen.

1.1.3. P-P-Sukzession

Auf extremen Standorten, die den ökologischen Ansprüchen von Klimax- und Intermediärbaumarten nicht mehr genügen, bilden Pionierbaumarten das Schlußwaldstadium. In diesem Falle gilt



Je nach den herrschenden extremen trophischen und hygrischen Verhältnissen handelt es sich dabei um Schlußwaldgesellschaften mit Birken (Betuletum pendulae, Betuletum pubescentis), Kiefern (Pinetum), Erlen (Alnetum), Pappeln (Populetum) und Weiden (Salicetum).

Auch bei diesem Sukzessionstyp konvergiert die Stoff- und Energiebilanz theoretisch gegen Null, sofern man hinreichend große Flächen und lange Zeiträume in die Kalkulation einbezieht. In Wirklichkeit ist das aber nur ein Mittelwert, um den die auf kleineren Parzellen und in kürzeren Zeitabständen gewonnenen Daten oszillieren. Die Schwankungsamplitude ist dabei weitaus größer als das bei P-K- und P-J-Sukzessionen der Fall ist (THOMASIUS 1988).

Der auf dem P-P-Sukzessionsschema dargestellte kleine Zyklus vollzieht sich bei den Pionierbaumarten wegen des hohen Lichtbedarfs auf wesentlich größeren Mosaikflächen und wegen der kürzeren Lebensdauer in erheblich kürzeren Rotationszeiträumen als es bei Intermediär- und Klimaxbaumarten der Fall ist. Von einem shifting mosaik steady state kann darum hier nur noch bei Zugrundelegung ziemlich großer Flächen die Rede sein. Damit ergeben sich bereits Übergänge zur Katastrophenverjüngung.

Mit Artenarmut, Gleichaltrigkeit innerhalb größerer Mosaikflächen, primitiver Raumstruktur und bescheidenen Rückkopplungsnetzen ist eine geringe Stabilität solcher Ökosysteme bei ausgeprägten Schwachstellen in der Alterungs- und Zerfallsphase verbunden. Dementsprechend sind flächenhafte Waldzerstörungen durch Feuer, Sturm, Insekten u. a. Faktoren keine Seltenheit und Katastrophenverjüngungen, bei denen die vegetative Vermehrung bzw. Regeneration eine größere Rolle spielen, mehr die Regel als die Ausnahme.

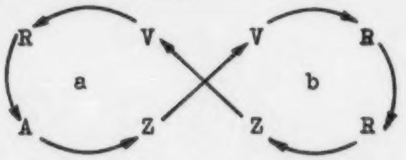
Die wichtigsten Unterscheidungsmerkmale von P-K-, P-J- und P-P-Sukzessionen (Alters- und Raumstruktur, Rotationsdauer, Stoffbilanz und Akkumulation, Selbstregulation und Stabilität), auf die in den folgenden Abschnitten noch einmal näher eingegangen wird, sind in Tabelle 2 zusammengestellt worden.

1.2. Autogene Sukzessionen mit divergierenden Stoffbilanzen

Unter ungünstigen ökologischen Verhältnissen, vor allem auf sauren und nassen Böden sowie bei niedrigen Temperaturen, kann ein permanentes Ungleichgewicht zwischen Detritusbildung und -abbau auftreten, das schließlich zu einer steten Humusanreicherung und damit Standorts- sowie Sukzessionsveränderung führt. Kennzeichnend dafür sind Rohhumus- und schließlich Torfbildung. Vielerorts kommt es in den borealen Nadelwäldern auch zur Ausbildung dichter Moospolster, die das Ankommen der Verjüngung erschweren oder unmöglich machen (KARPOV 1983).

1.2.1. Sukzessionen mit Baumartenwechsel als Folge autogener Standortsveränderungen

Mit Änderung des Standortszustandes wandelt sich auch die Wettbewerbsfähigkeit der Pflanzenarten. Dadurch kann es im Prinzip innerhalb eines jeden Sukzessionsstadiums zum Artenwechsel kommen. Das gilt besonders für die längerfristigen, von Waldbäumen geprägten Stadien. Zur Beschreibung dieses Prozesses benutzen wir folgendes Schema:



Dabei bezeichnen a und b die am Artenwechsel beteiligten Spezies.

Ein Beispiel dafür ist der Wechsel von Weißfichte (Picea glauca (Moench) Voss) zu Schwarzfichte (Picea mariana Britton) in Kanada und Alaska (VIERECK u. SCHANDELMEIER 1980). Von diesem unbalancierten Schwarzfichten-Schlußwald führt der Weg bei ungestörter Entwicklung zur Tundra bzw., nach einem Waldbrand, zu einem neuen Initialstadium der P-J- oder P-P-Sukzession.

Mit diesem Baumartenwechsel wird die zu einem Biomwechsel von der Taiga zur Tundra führende regressive Sukzession verzögert, aber nicht aufgehalten.

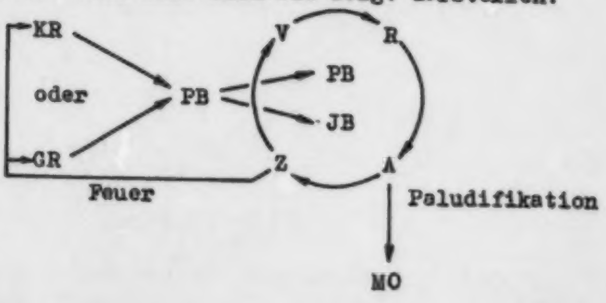
1.2.2. Sukzessionen mit Biomwechsel als Folge autogener Standortsveränderungen

Sind in einem der Paludifikation unterliegenden Gebiet keine für einen Baumartenwechsel geeigneten Spezies vorhanden, so kommt es bei ungestörter Entwicklung früher als im Falle 1.2.1. zu einem Biomwechsel vom Wald zum Moor bzw. von der Taiga zur Tundra. Dieser Prozeß kann sowohl aus der dunklen Taiga (P-J-Sukzession mit Piceetum-Schlußwaldgesellschaften) als auch aus der hellen Taiga heraus (P-P-Sukzessionen mit Betuletum- und Pinetum-Schlußwaldgesellschaften) erfolgen.

Dem hier beschriebenen Sukzessionstyp sind in Eurasien die Sphagno-Piceeten, Chamaemoro-Piceeten und Cladonio-Piceeten (z. T.) als unbalancierte Schlußwälder vor dem Biomwechsel zuzuordnen. In Nordamerika zählen dazu z. B. die von KABZEM, KOSOWAN und HARRIS (1976) beschriebenen Fichtenwaldgesellschaften auf mangelhaft, gering und sehr gering drainierten Standorten.

Alle diese Wälder gehen unentrinnbar ihrer Zerstörung entgegen. Im Falle fortschreitender Paludifikation müssen sie früher oder später der Tundra weichen. Dieser waldzerstörende Prozeß kann durch Waldbrände oder Kahlschläge rückgängig gemacht bzw. aufgehalten werden. Das ist aber ebenfalls mit einer Waldzerstörung verbunden. Der Unterschied zwischen beiden Wegen besteht darin, daß Waldbrände lediglich die gegenwärtige Waldgeneration zerstören und Voraussetzungen für weitere Waldgenerationen auf den gleichen Standorten schaffen, während Moorbildung eine Verdrängung des Waldes durch Tundrenvegetation auf unabsehbare Zeiten bedeutet.

Der hier behandelte Fall läßt sich wie folgt darstellen:



Tab. 2: Charakteristik des Schlußwaldstadiums bei P-K-, P-J- und P-P-Sukzessionen

Merkmal	Sukzessionstyp		
	P-P-Sukzession	P-J-Sukzession	P-K-Sukzession
Altersstruktur	nahezu gleichaltrig	zwei- und mehraltrig	vielaltrig entsprechend der Verteilungsfunktion $N = N_o e^{-ct}$
Raumstruktur . vertikal	nahezu einschichtig	meist zweischichtig	je nach Standort mehr oder weniger vielschichtig
. horizontal .. Mikrostruktur	POISSON- und Repulsiv-Verteilung	Cluster-Verteilung	Cluster-Verteilung
.. Makrostruktur	homogene Mosaikflecken sehr groß	homogene Mosaikflecken gruppen- und horstgroß	homogene Mosaikflecken truppgroß
Rotation der Mosaikflecken	100 Jahre (außer Kieferngesellschaften)	100 bis 200 Jahre	200 Jahre
Artenstruktur in Baumschicht	Pionierbaumarten, meist monospezifisch	Intermedialbaumarten, meist polyspezifisch	Klimaxbaumarten, meist polyspezifisch
Stoffbilanz und Akkumulation	Stoffbildungs- und Abbauprozesse asynchron, große Schwankungen der Stoffbilanz und Stoffakkumulation	Stoffbildungs- und Abbauprozesse nicht voll synchron, Schwankungen der Stoffbilanz und Stoffakkumulation noch beachtlich	Stoffbildungs- und Abbauprozesse weitgehend synchron, Schwankungen der Stoffbilanz und des Akkumulationsniveaus gering, Akkumulationsniveau hoch
Selbstregulationsmechanismen	intrakompetitive Rückkopplungen vorherrschend, interkompetitive und trophische Rückkopplungen gering ausgebildet	trophische und interkompetitive Rückkopplungen stärker als intraspezifisch ausgebildet	kompetitive und trophische Rückkopplungen gut ausgebildet und stark vernetzt
Stabilität gegenüber standortsüblichen Störfaktoren	gering, darum häufig großflächige Destruktion durch exogene Kräfte, Katastrophenverjüngung		großflächige Destruktion selten

2. Allogene Sukzessionen

Systematische Umweltveränderungen wandeln auch die Richtung der Sukzession. Dort, wo sich bereits ein Gleichgewichtszustand ausgebildet hatte (z. B. Sukzessionstyp 1.1.1.), wird so erneut eine sukzessive Wandlung induziert.

Solche Veränderungen als Folge einer sich wandelnden Steuergröße sind stets mit Ungleichgewichten verbunden.
Sie sind besonders groß, wenn dabei die ökologische Amplitude der bisher dominierenden Arten überschritten wird. Dabei ist zu beachten, daß derartige Prozesse nicht nur von der Art, Stärke und Dauer der Umweltveränderungen, sondern auch von der normalen Lebenserwartung und Generationsfolge der betroffenen Organismen abhängig sind. So ist z. B. ein trockener Sommer für Annuelle ein Ereignis auf Lebenszeit, für adulte Bäume aber nur eine kurze Episode.

Folglich sind Sensibilität, Reagibilität und Stabilität der Ökosysteme auch von der Lebensdauer der in ihnen dominierenden Arten abhängig. Ökosysteme, in denen kurzlebige Arten dominieren, sind einerseits sensibler, sie können sich aber auch rascher an die neue Situation durch Wandlung der Artenstruktur anpassen. Bei den von außerordentlich langlebigen Organismen geprägten Wäldern ist darum die Adaptationsfähigkeit an sich wandelnde Umweltverhältnisse außerordentlich gering (Abb. 1).

Dieser Einfluß auf die Lebensdauer korrespondiert natürlich mit einem schon wesentlich früher wirksamen Einfluß auf die Wettbewerbsfähigkeit der betroffenen Arten.

Kontinuierliche Umweltveränderungen im Verlaufe einer Sukzession können einen sowohl intra- als auch interstadialen Artenwechsel auslösen. Dieser ist um so stärker ausgeprägt, je größer die Umweltveränderungen und je enger die ökologische Amplitude der betroffenen Spezies ist. (THOMASIUS 1990).

Bei hinreichender Kenntnis der ökologischen Koordinaten der dominierenden Pflanzenarten einerseits sowie der Art und Stärke von Ökofaktorenänderungen andererseits lassen sich Voraussagen über sukzessive oder destruktive Ökosystemveränderungen machen. So ist z. B. bei einem Temperaturanstieg als Folge von Glashauseffekten mit einem Rückgang der Paludifikationsprozesse in den borealen Wäldern zu rechnen, so daß bisher zur Typengruppe 1.2. gehörige Fichtenwälder zu solchen der Kategorie 1.1.2. überwechseln können. Andererseits ist im südlichen Bereich der jetzigen Taigazone und an der unteren Grenze der montanen Fichtenwälder ein Rückgang der Piceeten zu erwarten.

Auch Luftverunreinigungen, besonders durch SO_2, vermindern die Wettbewerbsfähigkeit der Fichte. So kann sie aus den Bergmischwäldern (Abieti-Fagetum), wo sie ursprünglich als Mischbaumart vertreten war, verschwinden, und die Piceeten der orealen Stufe können sich in Sorbeten und Betuleten wandeln.

Diesen regressiven Entwicklungen in den Mittelgebirgen stehen Sukzessionen aus bisher nährstoffarmen Pino-Querceten zu Tilio-Carpineten als Folge signifikanter Nährstoffeinträge im Altpleistozän der DDR gegenüber.

4. Schlußfolgerungen

1. Im Verlaufe der Sukzession lösen sich verschiedene ökologisch und ontogenetisch differenzierte Stadien der Sukzession durch Dominanz markanter Lebensformen ab. Maßgeblich dafür sind neben der ökologischen Potenz allgemein vor allem die Präsenz, die Schattentoleranz und die Akkumulationsfähigkeit der Spezies. In der Regel werden schattenintolerante und wenig akkumulationsfähige Arten von schattentoleranten und gut akkumulationsfähigen abgelöst.

2. Die die Sukzession steuernden Umweltbedingungen unterliegen endogenen und exogenen Veränderungen. Unter günstigen ökologischen Verhältnissen konvergieren die endogen beeinflußten Faktoren gegen einen für das jeweilige System optimalen Grenzwert. Exogene Umweltveränderungen wurden bei Anwendung geologischer Maßstäbe schon immer beachtet. Bei Anwendung anthropogener Maßstäbe sind sie für waldökologische Untersuchungen erst in diesem Jahrhundert relevant geworden.

3. Im Laufe der Sukzession werden lebende und tote organische Substanzen gebildet und akkumuliert. Unter günstigen ökologischen Bedingungen bildet sich dabei ein von der Standortsfruchtbarkeit abhängiges, mehr oder minder stabiles und für das Systemverhalten wesentliches Stoff- und Energieniveau aus. Unter ungünstigen ökologischen Bedingungen kann es zu permanenten Anreicherungen toter organischer Stoffe kommen, die bei Störungsfreiheit nach Passage verschiedener Waldstadien (Taiga) zum Moor (Tundra) führen. Gleichgewicht ist darum kein allgemeiner, sondern ein spezieller Fall, der nur bei bestimmten Sukzessionstypen und in bestimmten Sukzessionsstadien auftritt.

4. Naturkatastrophen und anthropogene Einflüsse können die Sukzession erheblich beeinflussen. Sie sind nicht durchweg negativ zu beurteilen, sondern können geradezu Voraussetzung für die weitere Existenz von Waldökosystemen sein.

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LANDSCAPE ECOLOGY IN FORESTRY - A NEW CHALLENGE

Boštjan Anko

Associate Professor
Department of Forestry

Biotechnical Faculty
Ljubljana, Yugoslavia

FDC: 18: 907.1: 916

SUMMARY

Recent developments in forestry have created more room for landscape ecological considerations. Forming a new working body, dealing with landscape ecology, requires also some answers regarding potential mutual benefits both fields can expect. Attention is drawn to the similarities between forest and landscape as ecological and management systems and to the general parallels between forestry and landscape ecology. Landscape ecology could contribute to development of new forest management approaches in return it could be enriched and strenghtened by some traditional philosophies related to forest management that are applicable in management of other natural resources - including landscape - as well.

Keywords: forest, landscape, landscape ecology, multiple-use forestry

INTRODUCTION

Introducing a new scientific discipline to forestry and to IUFRO in particular inevitably raises some quite essential questions regarding the basic philosophies of the two disciplines involved and of their co-existence in general.

Some of the fields integrated into IUFRO by means of various working bodies are central, the others seem peripheral, some are extremely specialized, the others broadly integrating. All of these aspects are equally relevant for a balanced growth and development of forest science and practice. It is important therefore, for each working body, representing a given field of work to understand clearly its niche within forestry and its potential contribution to the development of forest science.

Some remarks on the basic interrelationship between forestry and landscape ecology, on the place and on the potential of landscape ecology in future forestry, presented here, should only serve as a beginning of a long

and hopefully fruitful discussion concerning the identity and the working program of the Working Party "Landscape Ecology" within the framework of IUFRO.

For the beginning one could start with the following three premises, which ought to be acceptable to most of us:

1. Forestry and landscape ecology are not strangers.
2. Landscape ecology could be instrumental in bringing about some fundamental changes in future forestry.
3. The interaction between the two disciplines can only enrich and reinforce them.

THREE COMMON DENOMINATORS

In dealing with forestry, landscape and landscape ecology one cannot ignore the vast differences in meanings these terms have to various people - in time and in space.

In order to facilitate further discussion we should, therefore, agree upon some very broad, commonly acceptable definitions of the three concepts in question: of the forestry, of landscape ecology and of a landscape as their meeting point.

Forestry means many different things to many different idividuals and communities alike. It can be the first agent in transforming primeval forest landscapes into cultural ones. It can also be the last defense of landscape's naturalness by struggling to preserve the last forest remnants - or trying to reintroduce them in man-dominated landscapes.

Forestry is everything between these two extremes: it can be greedy and rapacious - it can be ethical and even noble. The resulting confusion is well illustrated by the many definitions of forestry in various dictionaries - each reflecting a given natural, cultural, historical and socio-economic context: "Forestry is a science of developing, caring for, or cultivating forests: the management of growing timber" (Webster's Third New International Dictionary, 1971, p. 890), "... taking care, management, utilization of forest" (Wahrig, 1986, p. 493), "The science of planting and taking care of forests" (Webster's New World Dictionary, 1988, p. 528), "Economic activity dealing with silviculture and forest utilization" (SSKJ, 1970, vol. I., p. 740), "Care for and utilization of forests" (Petit Larousse, 1980, p. 893). And so forth.

Some might argue that dictionary definitions are not really the most reliable ones: true - but this is how we as a profession get introduced to and accepted by the general public. Not only are these definitions one-sided and obsolete (although many foresters might still find them acceptable): the matter of fact is that there is no room for landscape ecology in the forestry defined in this manner. For the purpose of further deliberations it could be suggested, therefore, that foresty be broadly defined as a *total of structured (organized) human activities related to all aspects of man-forest relations.*

Similarly broadly one should define also the landscape ecology. Ecology too - like forestry - means many diferent things to many different people - depending on their natural and cultural environment, educational background, objectives, etc. Its most precious contribution to man's thinking, i.e. its broadly integrating approach to addressing environmental problems, has been often misused and turned into its contradiction as each discipline, activity, interest group, etc. thought it found itself and justification of its interests in it. Thus, ecology often became "everybody's little acre", rather than the unifying principle . Unfortunately, there is no reason to believe that landscape ecology could be immune to similar dangers. From theoretical point of view, it is burdened by its geographical origin and heritage, and from the practical one by the fact that broadening its scope of considerations to sociosphere (noosphere) considerably increased the number of those who may want to see it as the final solution to various man-made problems - whithout really understanding what ecology is all about.

Odum (cit. Kormondy, 1965, p. 211) offered one of the most concise and elegant definitions of ecology by describing it as "study of the structure and function of ecosystems". Mutatis mutandis this definition can be easily broadened upon the landscape and, indeed, most of modern definitions of landscape ecology (Leser, 1976, p. 388, Forman, Godron, 1986, p. 11, Anko, 1986, p. 19, Golley, 1987, p. 2, etc.) seem to converge in this view. In doing so they do not differ among themselves as much in dealings with structural aspects as they do in considerations of landscape functioning - depending upon their professional ("ecological") background.

In order to facilitate the dialogue between forestry and this relatively young branch of ecology a definition of landscape ecology in terms of Forman and Godron (1986, p. 11) could be accepted, defining it as a study of:
- structure (distribution of energy, matter, and species in relation to the sizes, shapes, numbers, kinds and configurations of the ecosystems)
- function (flows of energy, matter and species among the component ecosystems and neighbouring landscapes)
- change (the alteration in structure and function of landscapes over time).

In expanding Odum's view of ecology from ecosystem into landscape due attention should be also given to spatial and temporal dimensions of landscapes and man's role in their metamorphoses - as well as to some intrinsic values, such as ethic, aesthetic and other transeconomic considerations which may become more strongly pronounced on the landscape level.

The third concept that ought to be broadly defined in order to avoid possible misunderstandings is the landscape itself. This definition is needed, because:
- landscape is an idea as well as physical phenomenon where forestry and landscape ecology (will) interact
- most of the cultural landscapes evolved out of forest landscapes
- the fate and role of forest in a given landscape in many ways reflect its distance (level of denaturalization) from the primeval natural landscape.

It is interesting to note that the authors of the above converging definitions of landscape ecology, differ considerably when it comes to defining a landscape. Leser writes of landscape as a "concrete ... landscape ecosystem of an *arbitrarily* extended sector of geosphere ..." (1976, p. 33)

and Golley considers landscape as a *"spatial* concept" (1987, p. 2). Forman and Godron (1986, p. 11) define landscape as a "heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form thoughout", and Anko (1986, p. 19) describes it as a "structural and functional synthesis of ... ecosystems, united by characteristic functioning". Similar division between the spatial and ecosystem (functional) approach in defining landscape seems to be running through a lot of contemporary landscape ecological writing.

If landscape ecology is to remain an *ecology* an if it is to serve as a theoretical basis for landscape (natural resource in general) management and restoration, then it seems obvious that forestry should adopt also in the future the ecosystem (functional) approach to it - as it actually did in the past. In maintaining natural balance of landscapes and in correcting old mistakes a turn to stronger emphasis on the flows of matter and energy seems to be unavoidable.

FOREST AND LANDSCAPE - SOME COMMON TRAITS AS UNIFYING FACTORS

As far as landscape ecology or landscape management are concerned forest is only a landscape component - like any other ecosystem. However, one could argue that there is a very special relationship existing between forest and landscape. Among many landscape components forest (in many countries, at least) remains the first among the equals - not without reason:

- forest was the matrix out of which many cultural landscapes have been carved. Its past or present distribution patterns therefore eloquently reflect in a manner of photographic negatives many givens and processes that created and transformed the existing cultural landscapes.
- unlike most other landscape components (modern managed) forest - just like the landscape itself - represents a multiple use system, expected to perform a number of functions (uses, services) at the same time.
- from the cybernetic point of view forest and landscape are live, undetermined systems, requiring planning and management approaches which draw attention to further similarities the two systems share.
- forest and landscape are ecological systems: no matter whether one deals with virgin forests or forest plantations, with ancient rural or modern urban-industrial landscapes, there are always some fundamental natural laws, governing their functioning and existence - regardless of the level of anthropogenic disturbances.
- similarities between forest and landscape exist also in their temporal dimensions. Some of forest organisms may be short-lived; the age of trees and stands can be measured in biological time - centuries at the most - but the forest itself can be eternal (compared to other landscape components) and its age only measured in geological time. Similarly, some of the landscape components are relatively short-lived, too - but the landscape itself can also be considered eternal - a puzzling conception to human perspective of time.
- forest and landscape have similar requirements also with regard to space: in order to be what they are, they need a "critcal mass" of land - a minimum amount of space to develop their identity by means of clearly discernible patterns of structure and functioning.

Some of the similarities between forest and landscape enumerated above should only serve in search of traits and problems common to forestry and landscape ecology.

FORESTRY AND LANDSCAPE (ECOLOGICAL) MANAGEMENT SHOULD NOT BE STRANGERS

Managing forests as a complex, multi-purpose component of a landscape bears so many parallels to the modern, landscape ecological concepts of landscape management - and vice versa -, of course, that it is really surprising to see how painfully inadequate - if not non-existent has been the co-operation between the two disciplines: landscape ecology has been cautiously exploring forestry-related problems, often misinterpreting and generalizing them. Forestry, by and large, simply ignored the newcomer to the scene - yet, they both need as close a co-operation as possible. Ignorance and professional jealousy are poor substratum for cooperation - let us rather look for things, we have in common, instead: the most important common aspect both disciplines share is their multifaceted character. Forestry contains four major groups of aspects, i.e. biological, technical, socio-economic and transeconomic ones. They are not only easily transferable to landscape study and management but are clearly indispensable for it. Dealing with a renewable resource forestry soon became aware of biological limits to forest production, renewability etc. In the purely technical sphere forestry again quite early faced the disturbing dilemma of deciding between the possible and permissible. The many aspects of man's dependence on forests clearly revealed that forests are not just another economic but really a socio-economic category in the broadest sense of a word. The above three groups of aspects inevitably lead into the fourth one containing the transeconomic aspects of forest management, born out of ethical questions, of environmental respect and responsibility, aesthetical considerations etc.

The complexity of considering the above four groups of aspects in any given situation can be further complicated by the request of maintaining their balance on a permanent basis. The principle ob sustained yield, originally meaning permanent, uninterrupted flow of income (as a result of uninterrupted timber production) can, namely, be easily interpreted as a principle of uniterrupted maintaining of desired combinations and levels of various functions of a multi-purpose forest. Similarly this tenet of the classical forestry can be expanded to modern landscape management as a quest for certain level of ecological stability and flexibility in the landscape on a permanent basis.

If the above similarities seem to be somehow abstract, then there others that originate from the common problems resulting from the nature of landscape and forest and from the character of the two disciplines themselves.

The first is the problem of how sincere we are in treating both, forest and landscape as living organisms. Of all the landscape components forests were practically the first to be consciously managed as ecosystems - and yet, there are many forestry practices to be found, all over, that are shamefully far from the much advertized "ecological approach" in forest management. Nature is not necessarily predictable, especially not in the long terms; as a

result it cannot be planned - only directed at best. Forestry frequently learned the truth of these truisms the hard way - many of our past mistakes in this regard need not be repeated in landscape management.

The next cluster of common problems is related to our perception of time. There are few human activities today with such broad time horizons as forestry and landscape management - even though the length of time spans that have to be considered in planning by both disciplines doesn't have the same roots, both they plan far ahead of any comparable activity. Considering long time spans is necessary because of the nature of forest and landscape but inevitably leads to conflicts because of the brief span of human life and even shorter time horizons of human interest. The slowness of processes in forest and landscape alike in comparison to human time pulse leads to underestimating the certainty of final outcomes and of cumulative effects of many natural and anthropogenic processes.

There seem to be problems also in our perception and mastering of space. Not only time but also spatial frames of forests as well as of landscapes often seem to exceed our understanding of space - particularly in practice. The main problem seems to lie in the fact that the ecological boundaries in space only seldomly coincide with those of our conceptual, legal, technical etc. control of space. The long life expectancy of a tree has taught forestry to think in long terms - unfortunately there is no such parallel to teach it thinking in broad spatial terms. Up till now forestry was fenced up within the existing forest boundaries - the view of forest "from without" has only seldomly prevailed - and yet it is the only kind of perspective in future management of forests and landscapes alike.

And lastly, one shouldn't neglect that multi-purpose character of forest and landscape draws attention to the fact that multi-purpose way of resource management (not really a common occurrence) inevitably leads into optimization rather than maximization as the supreme goal in management - a decision that doesn't require only ecological wisdom but ethics as well.

THE MUTUALLY BENEFICIAL INTERACTIONS

Applied sciences thrive on mingling of theory and practice. Forestry is no exception in this regard. Introducing ideas from other scientific areas has always made forestry better, that is, more open and responsive to its general environment - and stronger. And what is just as important - this has never been a one-way process. With its long tradition, ecological orientation and basic philosophies forestry of today and to-morrow can be viewed as a large testing field for foreign ideas and an equally fruitful seedbed of its own ideas ready to be transplanted elsewhere. There is no doubt that in view of the many common traits, forestry and landscape ecology can only benefit from closer co-operation and in the following we would only like to draw attention to some possible benefits to forestry in a crucial time of its development.

Caught in the old cage with the walls called area, standing stock, increment and cut, the traditional forestry in many regions has already exhausted its perspectives: the forest area has been shrinking, standing stock has been

rapidly depleted and the pollution brought about unpredictable decrease of increment. Under such circumstances also the cut is not what it used to be - a planned tool for ensuring sustained timber yields. Nevertheless, this is not the end of forestry: its declining share of GNP in many countries certainly does not reflect its true significance to them. It is not possible to think of the future of forestry in terms of timber production alone.

The real importance of forest can be appreciated only by considering all of its dimensions: not only production but also its environmental and even cultural roles it plays. Such a shift in views will inevitably result in significant shifts in the forestry itself.

The general direction of these shifts follows - in many ways - that of landscape ecology: the preoccupation with growing timber made forestry (in a strange way) self-sufficient and rather insensitive to other dimensions of the forest - and to many different expectations of people. In spite of the fact that forest takes up so much land the idea of forest as a (multi-functional) part of space has never been particularly deeply ingrained to forestry science - let alone to practice. In many traditional cultural landscapes forest distribution patterns have evolved as a photographic negative of developments in the sphere of farming. As a rule forests remained on sites least suitable for farming.

In the past forestry didn't take part in these processes. It was largely limited to managing forests within their boundaries - the extent of forest cover and its boundaries were not questioned: they were taken as givens. Such a stand could be considered understandable - from the point of view of forestry practice at least - it is most interesting, though, that it was never challenged by the forestry science. In the post-agrarian landscape many other land-uses have to be considered, showing even less understanding for and patience with the forest and everything it stands for than agriculture. In view of their aggresiveness the many dimensions forest has as a landscape component become even more pronounced. It is time therefore that forestry steps also "out of the forest" and begins to study and to manage it not only as a timber-field but also as the most natural ecosystem, gene pool, guarantee of biotic diversity, energy and matter dam in the landscape processes, etc.

This view of forest "from without" in broader landscape context will inevitably lead to new encounters and co-operations with disciplines which have been just as strange to forestry as forestry was to them. There is no doubt that landscape ecology will assume an important place among them.

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L'ETUDE DES STATIONS ET DE LEURS POTENTIALITES FORESTIERES EN FRANCE

Michel BUFFET

Coordonnateur du programme "Milieu" du CEMAGREF
CEMAGREF - 45290 NOGENT SUR VERNISSON

FDC: 18: 181.65: 62

RESUME

Après dix ans d'études régionales du milieu forestier, les premières tentatives de mise en relation de la production avec le milieu ont fait apparaître de grosses difficultés. Les principaux problèmes sont énumérés et des suggestions sont formulées tant pour orienter la poursuite des études de terrain que pour l'approfondissement des recherches.

Mots clés : Milieu, potentialité, production forestière, sol.

SUMMARY

After ten years of local studies about forest environment (soil and climate), the attempts to put together environment and yield-capacity have brought out large difficulties. Main problems are detailed and suggestions are proposed to improve local studies and to carry on research.

Key words : environment, forest production, soil.

1 - PROBLEMATIQUE GENERALE ET ENJEU ECONOMIQUE

Vais-je remplacer mes chênes médiocres par une plantation de douglas ? Le merisier, l'érable, le frêne ou le noyer peuvent m'apporter une production intéressante, mais mon terrain leur conviendra-t-il ? Quel clone de peuplier choisir pour valoriser telle plaine alluviale ? Peut-on prendre le risque de substituer à une hêtraie productive une autre spéculation plus intéressante ?

Ce sont là les questions les plus fondamentales et les plus lourdes de conséquences que puisse se poser le forestier.

Après s'être longtemps contenté de récolter les produits que lui offrait la forêt, l'homme s'est mis à en infléchir le fonctionnement à son profit, allant jusqu'à modifier la composition spécifique en fonction de ses besoins. Cependant le faible rendement économique du système ne permettant pas de modifier sensiblement le milieu (comme on le fait en agriculture) il est essentiel que l'essence de reboisement soit choisie, certes en fonction de l'objectif de production, mais, avant tout, en fonction du milieu concerné.

Une erreur sur ce choix peut coûter très cher : dans le cas le plus favorable, elle sera rapidement sanctionnée par la mort des jeunes plants ; mais, bien souvent il faudra attendre plusieurs décennies avant que ne tombe la sanction : production médiocre ou nulle, invasion d'insectes prédateurs, voire dégradation plus ou moins irréversible de la station.

Il est donc nécessaire de mettre à la disposition du forestier des outils simples et fiables pour caractériser le milieu, notamment vis-à-vis du comportement et de la production des espèces forestières. Et, bien que la France soit un pays d'ancienne tradition forestière, il est évident qu'il y a beaucoup à attendre d'une meilleure adéquation des espèces au milieu. Bon an, mal an, cela concerne les 50 à 100 000 ha de peuplements renouvelés ou créés chaque année.

Pour des raisons historiques (disciplines différentes) et des raisons de bon sens (simplicité) on a été conduit à étudier séparément le milieu et la production. Cela explique qu'aujourd'hui la démarche la plus courante consiste à ne réaliser une étude de production que sur une région qui a été, au préalable, convenablement décrite en ce qui concerne le milieu.

2 - LA DESCRIPTION DU MILIEU FORESTIER

Dans le courant des années 70 de plus en plus de forestiers ont commencé à ressentir le besoin de substituer à leur connaissance intuitive du terrain une description objective du milieu.

Le volume de la tâche à accomplir et la faiblesse des moyens conduisirent Becker à proposer un outil relativement simple et efficace : la typologie des stations. Très sommairement elle consiste à délimiter une région pas trop grande (10 000 à 100 000 ha) pour qu'elle soit assez homogène vis-à-vis du climat et de la géologie. Sur cette région une description précise du milieu, basée sur une enquête de terrain, aboutit au classement de l'ensemble des stations décrites dans un petit nombre de types (souvent une trentaine). Selon les régions et les sensibilités des opérateurs les paramètres observés sont variables (tapis végétal, sol ...) mais le produit final est toujours un catalogue de types, accompagné de clés d'identification des types qui permettent au forestier utilisateur d'identifier et éventuellement de cartographier les types.

Notons que cette approche n'aura d'intérêt que si se vérifie a posteriori l'hypothèse implicite que, dans la région étudiée, le milieu est réductible à un petit nombre de types et que ces types sont pertinents pour expliquer le comportement de la plupart des essences.

Actuellement, au bout de dix ans d'efforts un nombre important de catalogues de types de station ont été publiés à travers le territoire forestier français. Et l'on s'efforce de mettre au point des procédures d'extrapolation qui permettraient de tirer parti des études déjà réalisées pour couvrir rapidement le territoire non encore exploré.

Il convient de noter que la plupart des catalogues existants contiennent déjà des indications (rarement quantifiées) sur le comportement des espèces forestières et sur les facteurs susceptibles d'être limitants pour la production. Ces renseignements résultent soit de l'expérience personnelle de l'auteur soit d'enquêtes auprès des forestiers ; il s'agit d'une première approche, utile, mais qui ne peut pas remplacer une étude scientifique des potentialités.

Il est rapidement apparu qu'après avoir décrit le milieu, il devenait urgent d'étudier le comportement des peuplements en fonction des types de station. On s'est donc jeté à l'eau et l'on a essayé de mettre en route quelques études.

3 - EVALUATION DE LA PRODUCTION

Bien que toutes récentes ces premières tentatives ont très rapidement montré combien la tâche était difficile.

31 - Les difficultés rencontrées

Les principales difficultés résultent du fait que la production forestière, fruit de la croissance des peuplements, est un phénomène très complexe, sous la dépendance de nombreux facteurs et étalé dans le temps.

En première approximation on peut identifier trois catégories de facteurs de la production : le patrimoine génétique, le milieu (sol et climat), tout le reste (dont le forestier). Si on veut connaître la part revenant au milieu, il faut éliminer l'effet des autres composantes, qu'on les évalue ou non.

Composante génétique

Distinguons espèces indigènes et introduites :

a - Espèces indigènes
Proches de l'état sauvage, elles présentent une forte variabilité et on peut imaginer combien serait pervers pour notre propos une très possible adaptation à la station. Cela voudrait dire qu'il y a un génotype A sur la station A, un génotype B sur la station B, etc ... Il est alors impossible de comparer les types de station entre eux.

b - Espèces introduites
Le problème est différent : on peut imaginer que les reboisements d'une région constituent une sorte de patchwork de provenances qu'on ne connait pas. Le verdict est le même dans les 2 cas : on ne peut qu'élargir l'échantillon.

Le cas des plantations clonales est un cas limite où la base génétique est très étroite. Elle l'est tellement que l'information collectée sur les peuplements existants n'est guère utilisable pour les peuplements à venir (qui utiliseront d'autres clones).

La composante sylvicole et le rôle du temps

Sauf en peupleraie et en taillis simple, la production d'un peuplement et sa récolte sont suffisamment étalées dans le temps pour en interdire toute mesure directe.

Cependant en futaie régulière on sait que, sous des conditions assez strictes d'homogénéité génétique, d'âge et de fermeture, on peut :

- considérer les peuplements de divers âges comme les images successives d'un peuplement unique ;

- utiliser la hauteur dominante atteinte à un âge donné comme un bon indicateur de la production (relativement indépendant de la sylviculture suivie).

C'est l'existence de ces invariants qui a permis dans les années soixante de construire des tables de production pour un certain nombre d'essences bien représentées en futaie. Remarquons que la problématique était différente de la notre : le milieu n'était pas décrit et son influence était exprimée par un "indice de fertilité" qui rendait également compte de la génétique et de bien d'autres choses. D'autre part, pour la construction de ces tables, on recherchait systématiquement les "bons" peuplements c'est-à-dire ceux qui satisfaisaient le mieux aux conditions d'application des lois de Eichhorn.

Quand on recherche des relations entre milieu et production, on n'a pas le choix et on se rend vite compte que la grosse majorité des peuplements réels ne sont ni équiennes ni monospécifiques, ni complets. C'est le cas pour bon nombre de peuplements issus du régime du taillis-sous-futaie qui couvrent une importante surface dans la plaine française. Il n'y a plus, alors, à proprement parler de cycle de production identifiable, plus de comportement simple de peuplement. On doit se placer au niveau arbre et on constate que la croissance (y compris la croissance en hauteur) est fortement influencée par la niveau de compétition avec les voisins. La dimension atteinte par un arbre à un instant donné est fonction de son âge et de l'histoire de la compétition qu'il a subie.

Dans l'impossibilité évidente de décrire toutes les histoires possibles, on imagine trois sortes d'échappatoires :

. on s'intéresse au peuplement où la compétition est permanente et maximum, c'est-à-dire que l'on recherche systématiquement s'il existe des ilots de peuplement régulier de façon à rentrer dans le cadre des lois de Eichhorn ;

. On recherche le cas limite opposé dit de la "croissance libre" qui permet également de s'affranchir de l'histoire sylvicole ; on classera donc les stations à partir de la croissance en hauteur d'arbres dont on peut supposer qu'ils n'ont jamais été en compétition ; dans la réalité il semble que le cas soit rare ; on essaie de s'en rapprocher ;

. entre ces extrêmes, on étudie les arbres en compétition, mais en s'efforçant de mesurer cette compétition soit par la prise en compte des voisins (mais on ne connait pas les disparus), soit, ce qui est mieux, en recherchant dans l'arbre lui-même les traces de cette compétition (Volume du houppier).

Le climat et le temps

La notion de station inclut le climat et lorsqu'on l'utilise pour prévoir une production future, on fait l'hypothèse implicite que, hormis les fluctuations de courte période, le climat est invariant à l'échelle séculaire. On a de bonnes raisons de penser que c'est faux, et l'on se retrouve devant le dilemme suivant : ou bien, on se place au plus près du futur en n'analysant que les derniers accroissements et l'observation est perturbée par les variations annuelles, ou bien pour éliminer ces dernières on remonte dans le passé avec un risque de dérive du climat.

On peut adjoindre à la composante climatique les phénomènes de pollution, qui sont rapidement évolutifs.

32 - Les démarches possibles

Résumons :

- Si on peut disposer d'un échantillon suffisant de placette de futaie, on classe les stations sur la hauteur atteinte à un âge de référence, ce qui suppose un modèle de croissance. Ou bien ce modèle préexiste, ou bien on le construit soit sur des données instantanées soit sur des données suivies.

- Dans le cas contraire (pas de futaie régulière) on n'étudie plus des peuplements mais des arbres et on les choisit en compétition connue, si possible nulle.

Dans tous les cas, la difficulté d'accéder à l'âge a conduit à poser diverses hypothèses simplificatrices.

Jusqu'à présent nous avons supposé le milieu bien caractérisé par un catalogue de stations. Si ce n'est pas le cas on peut essayer d'expliquer la croissance des arbres grâce à des caractères du milieu choisis a priori. Cette approche dite "autécologique" a l'intérêt de la simplicité mais elle ne résoud pas le problème de la compétition. Bien entendu elle ne fournit pas de description spatiale du milieu.

33 - Prise en compte de la qualité

Pour certaines espèces la qualité pèse au moins autant que le volume produit dans le prix de vente obtenu. Mais, si le volume est une donnée à peu près objective, il n'en va pas de même de la qualité qui est largement fonction des usages futurs du bois.

La qualité dépend fortement de la génétique, de la sylviculture et du milieu mais on en sait encore moins que pour la quantité.

On s'intéresse en général à deux types de caractères :

- externes : morphologie, écorce ;
- internes : qualité intrinsèque du bois (couleur, infradensité ..).

Il pourrait être intéressant d'avoir une approche globale de la qualité en analysant les prix obtenus, mais cette approche se heurte à de nombreuses difficultés. Le prix ne dépend pas que de la qualité ; fonction du marché il fluctue dans le temps etc ...

4 - PREMIERS ENSEIGNEMENTS

Les premières tentatives pour mettre en relation milieu et production forestière ont fait apparaître de grosses difficultés (en particulier taille de l'échantillon, difficulté des mesures). Cela conduit, d'une part, à ne pas être trop ambitieux pour les prochaines études et, d'autre part, à développer des recherches.

41 - Bien identifier le probleme

Que cherche-t-on exactement ?

Le plus souvent il s'agit d'optimiser le choix d'un objectif de production sous un ensemble de contraintes économiques, techniques, voire affectives. On peut viser à court terme (20 ans) en se demandant à quel âge récolter des peuplements existants selon leur croissance. A long terme on s'intéressera au cycle de production complet et l'on comparera différentes essences.

Enfin il faut adapter ses ambitions à ses moyens : avant d'optimiser on peut peut-être se contenter d'éviter des erreurs grossières dans les choix. Il faut savoir se situer dans une échelle de précision qui va du coup d'oeil du forestier jusqu'à la mesure effective de la production en passant par l'indice de fertilité. L'appréciation de la qualité peut venir en complément comme elle peut être l'objet principal de l'étude.

Par exemple, pour le chêne, où l'éventail des prix est très grand, l'observation de la qualité est essentielle et la connaissance du volume accessoire. C'est l'inverse pour un taillis consacré à la production de matière première. Le cas de la hêtraie sera intérmédiaire.

42 - Poursuivre les recherches

Ces études ont eu l'immense intérêt de faire se rencontrer les spécialistes de deux disciplines : l'écologie et la dendrométrie. Cette démarche, enrichissante des deux côtés, doit conduire chacun à se remettre en question.

Du côté de l'écologie, il ne faut pas s'en tenir au catalogue de stations, désormais traditionnel ; pour mieux comprendre les relations entre sol et arbre il faut élargir le cadre géographique des études et s'intéresser à d'autres disciplines, géomorphologie, physiologie, etc ...

Du côté de la dendrométrie, il faut sortir de la futaie régulière, et approfondir la connaissance de la croissance et du développement de l'arbre en compétition. La modélisation s'appuyant sur l'observation du maximum de situations réelles devrait permettre d'avancer.

5 - CONCLUSION

Le forestier ressent le besoin d'être guidé dans ses choix qui touchent au milieu. L'enjeu est de taille. En dépit des grosses difficultés rencontrées lors des premières études, il faut continuer d'avancer.

Par ailleurs il ne faut pas perdre de vue qu'au delà de la prédiction de la production, une meilleure connaissance des interactions entre milieu et peuplement doit permettre au forestier de façonner une forêt plus saine et donc plus stable.

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LONG-TERM PRODUCTIVITY OF FOREST PLANTATIONS - STATUS IN 1990

Julian Evans

Chief Research Officer (South)

Forestry Commission Research Station
Alice Holt Lodge, Farnham,
Surrey, GU10 4LH, UK

FDC: 238: 114.5: 62

SUMMARY

The possibility of declining yields with successive rotations of fast grown plantations has concerned foresters. Specific examples have been reported this century from some sites in Germany, Denmark and South Australia and very locally in restricted parts of New Zealand and Swaziland. Each of these cases can be largely explained in terms of climatic fluctuations, specific nutrient deficiencies, weed competition effects, severe site disturbance at harvesting, or poor matching of species to site. There is little evidence to support the view that the intensive cultivation of a tree crop itself leads to loss of productivity in the next rotation, even if of the same species.

Yield increases between rotation can normally be expected owing to genetic and silvicultural improvements.

Exceptions to the general rule of no direct plantation effect may yet emerge in short rotation (<10y), mainly coppice, forestry.

Keywords: Productivity, plantations, yield prediction, site fertility

INTRODUCTION

Throughout the world there is increasing dependence on intensive forestry practices and in particular the establishment of forest plantations to supply wood requirements. The development of plantation forestry is almost wholly confined to the last 100 years with vigorous programmes of expansion taking place mainly in the last 40 years. Current rates of establishment are increasing, particularly in the tropics (Evans 1982), and by the year 2000 the World's man-made forest will contribute a large proportion of total industrial wood production (Sedjo 1987).

However, plantation forestry practice, compared with utilising natural forest, requires large capital investment in establishment and infrastructure, thus more than one yield or harvesting is required from the plantation site. Indeed, in the tropics, the economic life of most industries dependent on plantation produce is considerably longer than the rotation of the tree crop supplying the raw material. In such situations, quite apart from the desirability of high yields per hectare or proximity to a mill, it is unrealistic to assume that future wood supplies can always be met by planting new areas of land: second, third and subsequent crops of comparable productivity will need to be obtained from existing plantation sites. The simple question is, will these later rotations yield as much wood as the first?

Concern over maintaining yields is important not only because of the economics of plantation forestry but because it raises the whole question of what are the sustainable limits of a site's growth potential? Where natural forest is converted to plantation or plantations established in preference to managing natural woodland, the reason is primarily the expectation of superior growth rates and much higher yields. These expectations have generally been realised. In the tropics and sub-tropics, increment in plantations is commonly three to seven times that of natural forest. In the United Kingdom, yields from exotic conifer plantations are two to three times higher than from managed semi-natural woodland. In Queensland, Australia, cultural inputs of fertilising and cultivation have converted large areas of low yielding scrub into highly productive pine plantations. Numerous other examples may be cited of the successful use of plantations, provided species and sites are reasonably well matched (Zobel *et al.* 1987). But can ecosystems, formerly low yielding in wood, be turned permanently into more productive forest plantations or is the large initial gain only temporary? This question is the modern equivalent of the forester's traditional concern about maintaining or improving forest soil, about avoiding practices which may lead to site degrade - however defined, about using monoculture and clear-felling systems and, indeed, about stewardship of the environment of which the world's forests are so important a part.

Maintenance of productivity of plantations in the long-term, sometimes called "the second rotation problem", is an important topic because:

1. plantation programmes are expanding because of early successes and high yields of necessarily first rotation crops;

2. silvicultural practices today are increasingly intensive - genetic improvement, short rotations, harvesting of residues, selecting rotation age to maximise yield from a site, etc - such that the postulated causes of site degradation may be exacerbated;

3. the renewed interest in growing wood for energy will increase the use of forestry practices closer to farming in frequency of harvest and intensity of cropping *viz* short rotation coppice;

4. many plantations are established on infertile ground ill-suited to farming and possibly less able to sustain intensive forestry.

This review of the status in 1990 of the long-term productivity question briefly examines the history, and then summarises available evidence of yield change with successive rotation, from parts of the world where it has received most attention. Only limited comment is made concerning factors which may cause change in productivity. Detailed consideration is not given to regrowth forest, first rotation plantations on old forest sites, or coppice productivity in native woodland.

EVIDENCE OF PRODUCTIVITY CHANGE

Historical Perspective

The problem of maintaining or improving the productivity of successive crops is not peculiar to forestry; it was one of the earliest and most intensively studied subjects in both agriculture and horticulture. The nature of the problem differs between these three branches of plant cultivation in a way mostly reflecting the differences in time a crop is growing on a site. However, in essence the subject is the same; it is the understanding of the effect of a crop on its successor.

Arable farming relies heavily on new varieties, fertilisers, efficient pest and disease control, etc, to maintain level of output each year. Without these regular ameliorative treatments it is experimentally known that on nearly all sites the annual cultivation and harvesting of the same crop will lead to declining yields. In the Broadbalk field experiment at Rothamsted Experimental Station (UK), where wheat has been grown on some plots every year for more than 120 years, yields have fallen to about a quarter of the original before reaching a more or less steady state.

Horticulture lies between farming and forestry, since the same shrub or tree grows for several years on one site. And, in horticulture, Savory (1966), cites many instances of what are termed "specific replant diseases". The replant problem is defined as the poor growth of a second planting of a fruit crop which followed the same or a closely related species on a given site. The problem is peculiar to citrus, apple, cherry and peach, and is not caused by simple depletion of soil nutrients or soil degradation, as is usually the case with successive annual crops.

In forestry, taking the world as a whole, few plantations have reached second rotation, and where they have, the second crop is often superior, eg *Eucalyptus grandis* following *E "alba"* in Brazil, *Pinus nigra* var *maritima* replacing *P sylvestris* in eastern England, and *P radiata* replacing *P pinaster* in South Australia. Moreover, changes in site preparation or use of fertilisers can wholly alter a site, such that comparisons between rotations are meaningless from the point of view of assessing the effects of one crop on its successor. Nevertheless, there have been some reports of declining yields with successive crops of the same species.

From the beginning of the nineteenth century in Europe, in particular Germany and Switzerland, attention was paid to improving forest yield per unit area, primarily by converting broadleaved woodland to coniferous, mainly spruce, plantations. Check in some spruce stands appeared as early as 1833 (Jones 1965) and by 1869 a reduction in growth was observed in

young second rotation spruce on some sites (Troup 1928). By the latter half of the century there was a belief that the second rotation of the same species would not equal the first in growth rate and silviculture text books advocated use of mixtures because of what were being seen as dangers associated with coniferous monoculture. They also promulgated the view that once ground had yielded a timber crop it was unfit to yield a second of the same species, especially on sites initially ill-suited to it. In practice, pure stands mostly continued to be planted.

In 1923, these early fears appeared confirmed when Weidemann (1923) reported that spruce in Lower Saxony had declined considerably in yield in the second and third generations. This led many foresters to stress what were considered the dangers of conifer monoculture. Roth (1943) and Kasa (1947) reported similar declines in Switzerland and Norway respectively.

The implications and conclusions of Weidemann's study for NE Europe were not seriously challenged until investigations described by Holmsgaard and Holstener-Jorgensen (1961) and Holmsgaard (1966) showed little evidence for the assertion that successive crops of spruce always led to poorer growth, at least on sites investigated in Denmark.

At about the time of Weidemann's work reduced growth in second rotation teak in India and Java (Laurie and Griffith 1942, Griffith and Gupta 1948) and more recently in Senegal (Mahuet and Nomergues 1960) was reported. Though soil erosion is widespread under teak (Bell 1973), research in India has not generally confirmed a second rotation problem. Elsewhere in the tropics yield decline has not arisen with successive rotations of wattle (*A mearnsii*) grown in Africa for tan-bark (Herbert 1984, Lewis 1967). Other reported declines in successive rotations include *Pinus pinaster* in the Landes, France, though Bonneau, Gelpe and Le Tacon (1968) did not attribute it to site deterioration, Scots pine growing on sandy soils in Holland (Van Goor 1952), and in some plantations of Japanese larch in Japan (Asada 1966).

The most serious modern reports began to emerge in the 1960s concerning growth of second-rotation *Pinus radiata* in South Australia (Keeves 1966). The size oi the productivity decline was large (average 25% reduction), it occurred in 85% of second-rotation stands in the State, was with a commonly planted species, and developed under a silviculture typical of much plantation forestry in the tropics, sub-tropics and warm temperate regions where the first rotation shows excellent growth.

Keeves' report, was amplified by Bednall (1968) and Boardman (1978, 1979). Concern was heightened owing to similar results from the Nelson area of New Zealand (Stone and Will 1962, Bunn 1968) but the problem was not as serious as in South Australia and the decline in growth appeared to be largely transitory (Whyte 1973).

These reports from Australasia led directly or indirectly to several specific investigations into long-term productivity in plantations in South Africa (Schutz 1981), Swaziland (Evans 1975, Robinson 1973) and Tanzania (Lundgren 1978) as well as in other states of Australia - eg Victoria (Squire, Flinn and Farrell 1979) and Queensland (1979).

Status in 1990 of Long-term Productivity by Region

One preliminary point needs stating when reviewing reports of productivity changes. Generally speaking the beneficial effects of plantations on soils are only reported where degraded soils have been reforested or were under some evergreen tropical hardwoods. Added to this, and in addition to the examples of improved growth in the second rotation cited earlier, improved species choice, provenance, site amelioration, etc, better or at least maintained productivity in the second rotation is likely to be the norm and to be little remarked upon.

This review primarily concerns those regions where reports of yield decline have been made or postulated. Many of the reports have been specifically contributed for this paper by researchers in IUFRO group S1.02.09 and are noted by country with name shown in parentheses.

Denmark (Holstener-Jorgensen)

"Since the fifties and early sixties the first *vs* second generation problems have not been at question in Denmark. We believe all problems have been rejected by our research. It may, however, turn up again when present day quarrels about air pollution and soil acidification calm down and the public pressure to get more deciduous trees increases."

The Netherlands

According to Burg and Schoenfield (1987) developments in growth of 63 1st generation conifer stands and of 60 2nd generation conifer stands (Norway spruce, Sitka spruce, Japanese larch, Douglas fir) were studied on former heathlands in Drente. Site class increase averaged 2-3 classes after one generation. Changes in soil fertility were rather large during the first forest generation, due to fertilization (P, $CaCO_3$, K) at establishment. Raw-humus production still increased sixty years after the afforestation, except after reforestation. Foliar P concentrations were higher in second generation stands.

For the same sites Van Goor (1985) reported that growth of second rotation forest is generally 30 per cent faster than the first.

United Kingdom

Research has been confined to investigating the direct effects of trees on soil, eg Anderson (1987), and the long-term effects of afforestation and clearfelling on soil chemistry, soil water and drainage, (eg Adamson *et al.* 1987). Research programmes have concentrated on immediate restocking problems (Tabbush 1988) rather than yield change in successive crops. There is no mensurational evidence of yield decline arising from the effects of a tree crop on the site. The expectation is that productivity will gradually increase owing to genetic and cultural improvements. This assertion is borne out by data from Thetford Forest District, an extensive area of pine plantations established in the 1920s, which shows mean yield class of all conifers to be 12.11 $m^3 ha^{-1} y^{-1}$ in 1972 and 13.3 in 1988, the improvement arising from the steady replacement of

P sylvestris with *P nigra* var *maritima* for the second rotation. Further examination of the 1988 data shows the older crops, still predominantly *P sylvestris* have a mean yield class ranging from 11-13 and younger, mainly second rotation, ones of *P nigra* var *maritima* in the range of 13-14.5.

Elsewhere in Western and Central Europe Van Goor's (1985) review concluded that the role of tree species in maintaining soil productivity no longer formed an important topic for research.

Australia and New Zealand

A large programme of research, especially in South Australia, was undertaken following the alarming reports of the 1960s. The situation in 1990 is now very different, with superior growth of the second rotation occurring - see Boardman's (1988) excellent history. Since it has been the most important research programme, the contributions from Boardman and Nambiar for Australia, and Dyck for New Zealand, are reproduced in full.

(Nambiar)
"In Australia, the second rotation decline has been a problem in *Pinus radiata* plantations on podzolized sandy soils low in soil fertility and available water. There has been little or no evidence of such a decline on other soils or species.

Research by CSIRO and Forestry departments of South Australia and Victoria during the last decade centered around the 'Green triangle' (south east of South Australia and Western Victoria) had led to important management options which if applied judiciously can not only maintain but also increase productivity of successive crops. These options include:

- intensive management (including weed control and fertilization);
- retention of crop residue to maintain organic matter and nutrients;
- intercropping with lupins.

More recent research by CSIRO in collaboration with forest industries have provided comprehensive information on the dynamics of organic matter and nitrogen between crop cycles of radiata pine.

There has been great progress in applying the results of first class research on genetics and breeding to the benefit of the industry. This is being achieved by Southern Tree Breeding Association, a co-operative of major pine growers founded on breeding strategy developed by CSIRO.

Thus, through the application of the results of collaborative research on tree breeding, site management and silviculture, forest managers are confident of achieving increased productivity on sites which were once under the threat of '2R decline'."

(Boardman)
"Native soil fertility and the volumetric soil moisture storage capacity of South Australian forest soils interact to have a profound effect on maintenance of productivity on sites where rainfall is 650-900 mm y^{-1}.

Soils have been placed into three classes, fertile, moderately fertile and infertile. Infertility is usually defined by the availability of phosphate and zinc. Moderate fertility is constrained by poverty of phosphate, nitrogen and zinc. Productivity with soil classes is limited by availability of moisture during the spring and summer from winter recharge. Production class (YC) in first rotations without soil amendment, ranges from 18 to above 40 for fertile soils, from 12 to 34 on moderately fertile soils and from less than 7 to 30 on infertile soils. Second rotation (2R) productivity on replanted sites subject to near total slash disposal by burning and without soil amendment ranges from YC 18 to 29 on fertile soils, 15 to 23 on moderately fertile soils and 9 to 18 on the same infertile soils. The correlation between the degree of production class reduction and first rotation (1R) class has been found to be general for each class of soil fertility, including experimental sites with direct rotation comparisons on high level production class land.

Increasingly intensive silviculture has been introduced to capture the genetic gains arising from the radiata pine breeding programme. Assessment of productivity subsequently has shown that the decline reported in the mid-1960s has been reversed and currently stands at an average increase in productivity of 100% above the decrease typical of the previous extensive and minimal silviculture. It is apparent that there is a *potential* for decline in all replanting after a first rotation resulting from a change in native woodland or pastoral land use, but *not* in successive replanting. This effect is believed to be due to an intrinsic lower rate of nitrogen mineralisation in radiata organic residues than from broadleaved ecosystems (native forest and pasture grasses).

Field experiments and the gradual and serial introduction of intensive silvicultural practices, including slash retention, cultivation, rigorous weed control and degrees of refinement in the genetic source of seed, in conjunction with standard production class survey, have allowed us to estimate the average contribution of each silvicultural amendment.

Response has been described in incremental units of production class of the "unimproved" second rotation expected, ie addition to or subtraction from the yield class rating, namely, $m^3 ha^{-1} y^{-1}$. Of all ameliorative or retarding (eg poor weed control) practices only addition of nutrients has shown a significant trend with soil fertility class. The two largest contributory components have been rigorous weed control for the first 2 years after replanting and the introduction of 1.5 generation culled, limited polycross seed source.

The fundamental factors in the decline of the 1950s and '60s were the destruction of a high proportion of organic matter in slash disposal, causing significant loss of nitrogen and the seat of base exchange and subsequent near-stagnation in tree growth (for about 4 years) both caused by and exacerbating weed infestation which consumed most of the available soil moisture. In effect, this reduced the length of the pine growing season to a few months. The combination of these self-aggravating factors drastically reduced the nutrient flux density at a critical time in the life of the ecosystem. Feed back mechanisms since described by Torsten Ingestad and co-workers have gone a long way to explaining the persistent lower production which has conformed so closely to the trends of the yield

tables derived from first rotation permanent sample plots, a trend in poor production defined, apparently, so early in the subsequent rotation.

The findings are encapsulated in Figure 1 which shows yield classes on the left (as a yardstick for the rest of the columns), older practice averages and the typical response for the current intensive silviculture (which has now been refined; since site quality assessment takes place at 9.5 years there is a lag in data). On the right are results from two similar comparisons on high production class sites, of 1R and 2R on the same site given identical treatment except that, in the second, half-sib families were examined individually in a progeny test component. Ameliorative treatments were raised close to, and in some cases in excess of, limits of input (albeit relatively crudely) in a "go for broke" approach.

Results were so outstanding that I was interested to find how close we were approaching limits to growth without irrigation, ie a practical limit to efficiency (100% PLE = 4.9% PAR) set by ultimate "design" constraints. Peak productivity by family 80055 at 74% of this limit is astounding. The message is that the way to increase productivity further lies squarely with breeding and genetic engineering - and we are going hard in that direction."

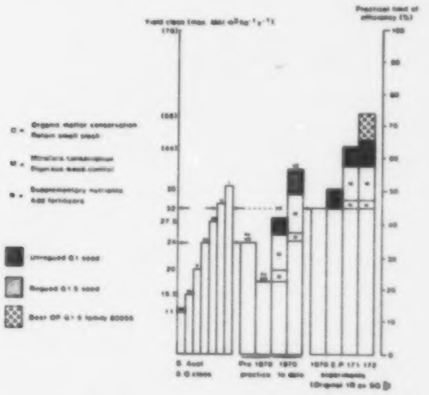

Figure 1: Changes in productivity in S Australian *Pinus radiata* crops over time (R Boardman).

Research in similar conditions in the State of Victoria has entirely confirmed the benefit of organic matter conservation and rigorous control of competing weeds (Turvey and Cameron 1986a, 1986b, Cellier *et al* 1985, Squire 1983, Squire *et al*. 1985). In Queensland, second rotation *P elliottii* on the same site and of identical seed origin showed 17% higher volume per hectare at 9y where organic matter had been conserved (Bevege and Simpson 1980). More generally use of *Pinus caribaea* x *P elliottii* hybrids on wetter sites and better provenance selection is expected to lead

to substantially better second rotation growth than first (Shea 1987). Second rotation *Araucaria cunninghamii* is also reported superior to first.

In New Zealand, concern over yield decline largely focuses on direct harvesting and soil disturbance effects rather than effects of trees themselves on site (Dyck and Skinner 1988, Dyck and Cole 1989).

(Dyck)
"There is little direct evidence that forest harvesting practices have caused site productivity decline in New Zealand. The lack of evidence is largely because few studies have been conducted that adequately address this problem. There is limited evidence available from retrospective studies that indicates that for some soil types, site preparation practices may have reduced second-rotation productivity by as much as 40%. Carefully-designed, long-term field trials, together with appropriate process-orientated studies, are required to improve our understanding and to enable extrapolation of trial results to other sites. Site classification systems and computer models should be developed to integrate knowledge but these tools require process studies for establishing modelling parameters and long-term research trials for validation."

South-east Africa

Most interest has concerned the pine plantations of the Eastern Transvaal (S. Africa) and Swaziland and Black wattle mentioned earlier.

(Schutz - S. Africa)
"There is no evidence of any decline in productivity of pine plantations over successive rotations in either the summer rainfall area or the winter and constant rainfall areas, other than small-scale growth reductions resulting from localized compaction of susceptible soils. Excessive accumulation of undecomposed litter in stands of *Pinus patula* (to over 300 t ha^{-1} oven dry mass) on some sites are, however, giving rise to concern over possible increasing soil acidity and immobilization of nutrients within the litter. No other productivity problems are expected."

In Swaziland, many *P patula* stands in the Usutu forest are now third rotation and the most recent assessment of growth shows that most are at least as productive as the second at 6 years of age, with the exception of one area where continuing yield decline is occurring (Evans 1986). About 15% of the forest is affected and appears to be due to phosphate deficient soils and, owing to slower establishment, more severe weed competition after planting (Evans *op cit*, Morris 1987). Trials indicate that phosphate fertilising largely corrects the yield decline.

N America

(Gessel)
"Although many statements have been made about the potential for declining yields in successive plantations in the Pacific Northwest, there is no clear evidence to support these. Environmentalists have used these statements to attack the practice of clearcutting, a widely used forest harvest system in the Northwest. Because considerable areas of forest land

are still in the original forest cover and most of the remainder has been put to non-forestry uses or is in the first rotation, there is not a good basis for definitive statements. In fact, the data base for first rotation growth to the original forest in general is lacking. One subject which has received special attention is the effect of fire because of its use to clear logging slash. Results from the many studies range from depression of subsequent forest growth to a stimulation, depending upon the local conditions of soil and site. We do know that nitrogen supply is frequently the limiting factor in initial forest growth and that harvesting methods, or other treatments, which reduce available nitrogen will depress plantation growth in the early years. This deficiency can be corrected by nitrogen fertilization.

Some of our forest soils can also suffer from compaction and erosion if logging is done improperly or when soils are extremely wet. A number of studies have shown reduced growth of planted seedlings on compacted skid roads or areas of soil loss. These reductions relate to specific areas receiving the wrong treatment and not general plantation areas.

In summary, potential forest growth decline problems in second or third plantation rotations in the coniferous forests of the Pacific Northwest relate to two major causes.

(1) Compaction or loss of soil through erosion by improper harvesting. These changes are significant on heavier textured or shallow soils.

(2) Loss or reduction in available supply of an essential element, such as nitrogen, especially on soils with a limited initial supply.

If these two potentially detrimental changes are avoided in harvesting and regeneration of Northwest forests, then there seems to be no evidence of an overall decline in growth and yield of successive plantations."

Throughout the US a coordinated series of experiments are planned to assess long-term impacts of management practices, the practicability of restoring degraded sites and assessing potential for enhancing productivity (Powers *et al*, 1988).

Other regions and crops

Few other reports of mensurational evidence of yield change have been published apart from productivity of successive cycles of coppice. Both in temperate regions and the tropics yield differences between rotations are often more to do with tree physiology, stump mortality, stool cutting method than site exhaustion as a result of coppice forestry itself - see Evans (1982), Kondas (1982) and Rollinson and Evans (1987).

PROBLEMS OF DATA COLLECTION

Despite the above reports and much circumstantial evidence pointing to change in site conditions due to growing forest plantations there are, in fact, surprisingly few reliable and documented examples of yield change between rotations. It is important to emphasise the reasons, which fall

into three categories, - paucity of data, problems of measurement, and the problem of exact comparison, and have been reviewed by Evans (1984).

Throughout the world the area of second or later rotation plantations is relatively small; most afforestation has taken place in the last 40 years and most stands are still first rotation. However, even where second rotation stands do exist, few assessments of yield change have been made. Managers rarely perceive the problem as urgent. Small changes are considered unimportant and very difficult to detect anyway. The first crop will often not have been carefully measured and, necessarily, the assessments will be over very many years and usually many decades apart with the likelihood of the earlier records being lost. Moreover, concern over the long-term productivity problem usually only arises once the second rotation is well established, by which time even the opportunity of examining growth of the previous crop by stem analysis is gone apart possibly from the uncertain analysis of stump rings.

However, even where assessments have been made, precise comparison of yields between rotations can still be difficult. Measurement accuracy and convention may change and even the measurement units over the period of a rotation. When absolute measurements are unavailable and site growth potential only estimated, eg site index, quality or yield class, commonly the method of estimation will have been improved or even changed. Not only are different systems notoriously difficult to compare, but stands are assigned to broad classes rendering small changes undetectable.

The third problem is that of making exact comparisons between rotations not invalidated by inherent site differences or the apparently simple requirement of measuring to the same age. Several sub-optimal solutions are discussed in Evans (1984) but the only certain method is to re-establish the permanent sample plots of one rotation on the same site in the next. This is now incorporated in some sample plot programmes eg India (Ravichandran and Dury 1989) and USA (Powers *et al.* 1988) but is not, for example, an explicit objective for permanent sample plots in New Zealand (Pilaar and Dunlop 1989) nor United Kingdom apart from long-term reference sites set up as part of an environmental change network.

DISCUSSION AND CONCLUSIONS

This review has revealed that there is little direct evidence that intensive plantation forestry practice will itself lead to decline in productivity with successive rotations. In almost all locations from where reports emanated in the past indicating concern, the explanation for observed lower yields has become much clearer with the postulate of site exhaustion or direct nutrient removal low on the list of contributory factors. In most cases the role of weeds, especially grasses, and their effect on moisture status in the early years after planting/replanting is recognised now as most significant; no longer is it enough simply for the leading shoot to be above competing weeds - too high a penalty will be paid in checked growth from below-ground moisture competition. The second main ingredient to good second crop performance, reported in several instances, is minimising disturbance and soil compaction and conservation of organic matter and harvesting residues between rotations.

With attention to the above silviculture the expectation of improving yields with successive rotations through tree improvement programmes remains sound. This is the position in 1990; overstress of sites is uncommon and, where appearing to occur, can be contained or corrected.

One exception could still be very short rotation (1-7 y) energy crops. These are of recent origin, mainly since mid-1970s, but few data exist to indicate whether they are potentially more stressful. Nutrient removals by short rotation poplar crops in Britain do not suggest cause for alarm but, clearly, as this form of forestry approaches arable farming practice in its intensity yield changes will need close examination.

Overall, three conclusions may be drawn from this review.

First, there are still few data about the growth of successive crops on one site. The need to provide for the collection of relative performance data between rotations must be part of all plantation programmes so that the long-term productivity question can be monitored. Clearly there is also a need for specifically designed studies on yield and site changes between rotations, particularly in view of climate change.

Secondly, it does not appear yet that declining productivity will be a feature of successive rotations of most species on most sites. Indeed, maintained or improving growth rates are more likely scenarios as improved seed origins and cultural practices are used. However, on some sites, especially those that are inherently fragile or infertile, careful harvesting practices, conservation of organic matter, and good weed management are crucial practices to maintain productivity.

Finally, it must be remembered that there are few second rotation stands and fewer of third and later rotation. The above optimistic conclusion may not hold in the long-term. As forestry becomes increasingly intensive the expectation must be for greater inputs from crop improvement, cultural practice and levels of protection to maintain yields, quite apart from coping with climate change. You never get something for nothing.

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POTENTIAL NUTRITIONAL PROBLEMS IN MAINTENANCE OF LONG TERM SOUTHERN HEMISPHERE PLANTATION PRODUCTIVITY

S. P. Gessel and J. Turner[1]

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Introduction

Countries in the Southern Hemisphere have established over 8.8 million hectares of forest plantations. Of these approximately six million hectares are coniferous and the remainder hardwood, predominantly *Eucalyptus* (Table 1.). The single most widely planted coniferous species is *Pinus radiata* of which approximately 2.7 million hectares have been planted. The present rate of plantation increase is approximately 190,000 ha/year, predominantly using conifers. There has been a large investment in plantation establishments and these are predominantly exotic species. The main reason for this investment being the higher productivity than the natural forest vegetation, and further, exotics are often selected to provide wood having specific properties that are not present in the native species. For example, plantations were established in Australia as the local supply of coniferous timber was very small as the native forests were dominated by hardwoods of the *Eucalyptus* genus.

Table 1. Estimates of forest area and the area of forest plantation on a continent basis in the Southern Hemisphere (Forest area from F.A.O. 1985).

Continent/ Area	Plantation (ha x 10^3)			Forest Area (ha x 10^6)
	Conifer	Hardwood	Total	
Africa	1087.8	673.3	1761.1	161.7
South America	3174.8	2078.1	525.9	710.5
Australasia/Oceanica	1760.9	18.3	1818.2	179.2
Total	6025.5	2769.7	8827.1	1051.4

Plantations generally produce in the range of 15-25 m^3 ha^{-1} yr^{-1} (MAI) merchantable volume, with some producing over 30 m^3 ha^{-1} yr^{-1}. The plantation productivity may be compared with 1-7 m^3 ha^{-1} yr^{-1} for many natural forests (Evans 1984). The variation is dependent upon species,

1 Professor Emeritus, College of Forest Resources, Univ. Of Wash. Seattle and Chief Research, Forestry Commission, New South Wales, Sydney, Australia

(Turner and Gessel, 1989). This estimate was crude as a substantial proportion of the plantation area was at a pre-commercial age and hence productivity would be higher. However, in Australia 4.6% of the productive forest area in the form of plantation produces 54% of the countries wood. In New Zealand softwood plantations produce 9.27 million m^3 of wood in 1985/86 this being 94% of production (Anon, 1988) and in Chile 7.5 million m^3 from *P. radiata* plantations or 91% of production (Anon, 1987b). The Chilean plantation represented 9% of the forest area. One characteristic of many of the Southern Hemisphere plantations is the rapid expansion in more recent years so that the age class distribution is generally dominated by the pre-commercial range. In Chile, if 15 year-old is considered the average age of lower age for commercial production then 70% of the total plantation area is un-merchantable.

The increase in plantation forest areas, their generally high productivity and the increasing intensity of forest management requires that the longer term implications for forest productivity need considering. There have been indications that on poorly buffered soils, there may be declines in productivity in subsequent rotations (Ref), or measureable declines in nutrient status (Morris, 1984).

Site Considerations

Native forests have evolved in relation to soil and site characteristics and hence, over relatively small areas species will change as moisture, nutrient and other factors change. While a soil may be low in nutrients, nutritional deficiencies are not apparent as the species are adapted to those sites (Lambert and Turner, 1983). However, most plantation areas have been established with little regard for this variation in site, and often, such as an old pasture, the subtleties of site may be difficult to characterize. One result has been the development of a range of nutritional and other stress related problems reported in plantations, the specifics of which vary with soil type (Turner and Lambert, 1988a).

Plantations are established on land covered by existing native vegetation, on areas previously used for agriculture or by rehabilitation of degraded land. Research in many areas has concentrated on site classification and selection (Turvey 1980, Turner and Holmes 1985, Schlatter *et al.*, 1982, Grey, 1989). In some locations the classification systems has aimed at matching species in broad site categories, for example, in Southern Africa *Eucalyptus saligna* is planted on moister sites and *Cupressus lusitanica* on drier sites. In other areas where plantations are dominated by one species the aims have been firstly to select suitable areas or regions and secondly to select or classify specific sites within those. In the case of Regional selection various models have been proposed using a range of parameters. As an example, for *Pinus radiata* climate is the major factor on the broader level and soil factors become more critical at the finer scale. Thus, in seven Regional models for *Pinus radiata* from Australia, Chile and New Zealand (Table 2), rainfall is the only significant parameter in all.

Table 2. Factors used in Site Index prediction equations of *Pinus radiata* on a regional level.

Auther er al.	Czarnowski et al. 1971	Booth et al. 1984	Cox 1982	Garcia 1982	Hunter and Gibson 1984	Jackson and Gifford 1974	Schlatt et 1982
Country	Aust.	Aust.	Chile	Chile	N.Z.	N.Z.	Chile
Rainfall	•	•	•	•	•	•	•
Soil Depth	•				•	•	•
Soil cations & a	•	•		•	•	•	•
Soil phosphorus & b	•	•			•	•	
Soil water		•		•		•	
Slope		•	•				
Altitude		•	•				
Organic matter &				•			•
Resistance/ bulk density						•	
Temperature					•	•	
Stand age &				•		•	
Soil nitrogen &						•	
Soil pH &					•		
Humidity	•						
Soil series			•				
Distance to sea				•			
Latitude							•
Texture							•

& The parameter is greatly influenced by the stand
a Either single cations or a function combining several cations.
b Usually available P (Bray or Olsen), but may include total P.

One site classification system, developed for management purposes, is a *P. radiata* Soil Technical Classification (Turvey, 1987). The characteristics are identifiable in the field, that is, laboratory analyses are not required, and are species specific (i.e. for *P. radiata*). These two characteristics, plus that of being readily computerized, are critical for routine and rapid implementation. Many other system studies are of explanatory value but may be difficult to implement or the factors included are not independent of the existing tree crop (Ballard 1971, Grey 1989). The classification of sites not only related to the identification of productivity classes but also for identifying management problems such as trafficability, compaction and potential decline (Murphy, 1983). The more intensive forest management becomes in term of inputs and increasing timber yield, the greater is the requirement for detailed site information.

Apart from specifically identifiable soil characteristics the land use prior to plantation establishment needs to be considered. In some areas it has been identified that sites which were previously agricultural or grassland may have higher productivity. Australian evidence indicates that *Pinus radiata* planted on previous agricultural or grassland may have

higher total productivity but results in trees with considerably higher deformity than areas which previously supported forest, leading to less merchantable yield (Table 3). The type of deformity is quite variable, and there may be interactions with nutrients, such as boron, leading to reduced apical dominance. However, it appears that the high level of soil nitrification and nitrate on grassland sites is the main causative agent. Two year-old plantations of *Pinus radiata* on previously improved pasture sites had mean monthly total mineral soil nitrogen concentration of 16 mg N/g of which 33% was in nitrate form. By comparison unimproved pasture has 2% and in 15-20 year-old stands the levels were negligible (E. Birk *pers. comm*). After establishment crown closure and the development of a forest floor nitrification declines to that expected in a normal forest situation, and the question arises as to whether this is a continuing problem in subsequent rotations. The establishment methods on these sites will need to include those that lead to rapid crown closure (e.g. closer spacing), suitable selection of genetic stock, form pruning, careful selection of fertilizer treatment (e.g. non-nitrogenous fertilizer) and weed control. The deformity problems of pine on pasture sites have also been noted in *Eucalyptus* plantations located on ex-pasture sites.

Table 3. Comparison of adjacent 22 year-old *Pinus radiata* plantation establishment on previous forest and pasture (E. Birk. *pers. comm*).

	Previous Land Use	
	Native Forest	Pasture
Volume (m^3/ha)	370	469
Stems/ha	1020	1440
Forked Trees (%)	9	19
Ramicorns (%)	20	40
Leader Damage (%)	19	33

Site selection is important in plantations and becomes more critical as the level of management intensity increases. Evidence exists that the land-use prior to plantation establishment will be important in subsequent productivity and the merchantability of the forest. Research into site and site characteristics in relation to both species and proposed management practices requires further work.

Maintenance of Productivity

Maintenance of plantation productivity includes assessing practices and problems which both reduce productivity and increase productivity. On sites, some sites are sensitive to the impacts of specific management procedures and hence the need to use classification systems to delineate these areas. For example, the sandy soils in South Australia are sensitive to loss of nutrients through such practices as intense burning of residues (Flinn *et al.*, 1979).

Soil compaction as a result of forest management is a major problem affecting water and nutrient availability, root penetration and, consequently, tree growth. Compaction particularly becomes a problem while harvesting during wet weather logging, and can lead to significant reduction in tree growth. In Southern Africa Grey and Jacobs (1987) reported tree height reductions of 26 to 59% attributed to soil compaction (Table 4).

Table 4. Harvesting impacts on soils in Southern Africa.

Species	Age (Yrs)	Impact Area (%)	Reduction in height growth (% 3)
E. grandis	1.1	12	44
P. radiata	1.6	14	59
E. grandis	4.8	12	28
P. elliottii	9.0	98	26
P. patula	16.0	36	33

The potential for increases in plantation productivity needs consideration. Considering the wide range of sites, climate and species there are a large number of nutritional problems, for both macro and micro-nutrients. Further, even without existence of apparent deficiencies fertilizers have been found to stimulate growth if applied at specifically identifiable periods in the rotation.

Fertilizers have been successfully used to overcome obvious deficiencies, at establishment, as a booster prior to crown closure and after thinning (Turner and Lambert, 1986a). The optimal growth responses are a result of using the correct fertilizer type, quantity, method of application and at the correct time. That is, the treatment has to be matched to the site and stand conditions, this requiring appropriate research data bases.

Fertilizer treatments at time of establishment may be considered as two types, one is a small application which produces the equivalent of one or two years additional growth. This may in part be overcoming the restrictions of root development in planting holes. Secondly, larger doses, usually of phosphorus, producing long term responses, the addition of fertilizer nutrients in this case being a large amount of nutrient in relation to the quantity already in the soil (Table 5).

Table 5. Quantity of phosphorus applied, quantity of phosphorus present in the top 10 cm of soil, and growth response for *P. radiata* on various locations. Mean annual increment estimated for total stand age (From Turner and Lambert 1986b).

Age fert. applied (yrs)	Period of growth (yrs)	Quantity applied (kg P ha^{-1})	Quantity in top 10 cm soil (kg P ha^{-1})	(%)	Volume growth (m^3 ha^{-1} yr^{-1}) cont.	fert.	diff.
0	16	100	125	80	0	9.7	9.7
2*	16	100	61	164	2.3	7.5	5.2
4*	17	75	70	107	2.6	11.4	8.8
9	13	115	92	125	7.8	15.1	7.3
13	11	115	61	188	16.0	20.4	4.4
20	17	225	147	153	2.5	17.0	14.5

* approximate age as stand regenerated naturally after clearing the first rotation.

The large treatment of phosphatic fertilizer broadcast applied either at establishment or prior to crown closure often has a long term residual effect. This residual effect is dependent upon factors such as the phosphate fixing capacity of the soil where, if it is low there will be substantial fertilizer loss and if high there will be little available P. The residual effect has been measured over long periods (Flinn *et al.*, 1979 Ballard, 1972) (Turner 1982, Gentle *et al.*, 1986 Woollons *et al.*, 1988). The study of Gentle *et al.* (1986) had one treatment of fertilizer and this was followed over two rotations where the response was still very apparent (Table 6).

Table 6. Comparison of *P. radiata* merchantable volume (m^3 ha^{-1}) measured at the same age (16 years) in first and second experimental rotations (Gentle *et al.*, 1988). Phosphorus treatments (92 kg P ha^{-1}) were applied once.

Rotation	Treatment: Rock Phosphate	Superphosphate	Control
First	118	128	38
Second	135	145	52

The application of superphosphate led to increased productivity (Turner 1982) and accumulation of organic matter and other nutrients in the upper horizon of the soil. It was considered that after clearfelling

management should aim to maintain these levels in the subsequent rotations by conservative practices aimed at retaining nutrients (Turner and Lambert, 1986).

Optimum responses to fertilizer applications at planting require suitable weed control. This has been found the case for most species and becomes more critical where water is seasonally limiting. As an example, Squire (1977) looked at the interataction of site preparation, weeds and fertilizer applications on *P. radiata* at time of establishment indicating a major interaction (Table 7). Fertilizer alone had a minor impact on growth but the combinations of treatments had a major effect.

Table 7. The basal area increment (5 cm above ground, cm^2/tree) for *Pinus radiata* at two years of age with different site preparation, weed control and fertilizer treatments (Squire, 1977).

	No fertilizer applied		Fertilizer applied	
	No grass control	grass control	No grass control	grass control
No site prepartion	1.23	3.69	1.36	7.55
ripped	1.57	4.87	1.89	9.23
ploughed	1.52	5.90	2.18	10.96

Fertilizers have been effectively used after thinning to increase productivity of plantations. Biologically the greatest growth responses have been obtained in the younger stands after first thinning, however, the best economic responses are to be obtained if the treatment is applied to older stands where there is an increased yield of higher value wood. The fertilizers used in this case are usually nitrogenous with varying amounts of phosphorus and other nutrients (e.g. B) depending upon the nutritional status of the site (Turner and Lambert 1986, 1987).

In general the stresses in plantations arising due to the site conditions not being optimum for the species have shown up as reduced forest growth and/or development of nutrient deficiency symptoms. However, stress within apparently healthy trees may be reduced resistance to pathogen or pest attack. Sulphur deficiency in *Pinus radiata* has been shown to allow accumulation of the amino acid arginine and this has allowed rapid development of the fungal disease *Dothistroma* (Lambert, 1986). The sulphur deficiency may be reduced by nitrogen fertilizer applications (Lambert, 1986). The pasture sites, with high available nitrogen and low sulphur also are prime situations for this form of stress. In Australia *Eucalyptus* species when planted off-site are often placed under some stress and this has manifested itself in heavy defoliation of plantations by leaf eating insects (Pryor and Clarke, 1964).

Forest plantation productivity can be maintained and increased, however the management treatments involved do need to be matched closely

with the site and species. Further, the indications of stress in trees, other than reduction in growth need to be monitored.

Impact of Management

The impacts of plantation establishment in relation to potential timber yield and other factors, such as water yield and quality, need to be constantly reviewed. This is more so with intensified management and potentially shorter rotations.

The plantation species effects on soil, such as in the form of increased podsolization, have attracted considerable attention. Changes in soil properties under plantations can be measured when compared with adjacent native vegetation. However, whether the effects are a result of plantation pasture (i.e. increased yield, soil disturbance) is often difficult to determine. Turner and Lambert (1988) considered the impact of planting *Pinus radiata* over a range of sites. The study showed that the surface soil total nitrogen declined under plantations, but that this was primarily a redistribution into the more rapidly growing plantation biomass, Table 8.

Table 8. Above ground organic matter and nitrogen distribution of a 35-year-old *Pinus radiata* plantation and an adjacent *Eucalyptus* stand (Turner and Lambert, 1988).

	Pinus radidata		*Eucalyptus*	
	Organic matter (tonnes/ha)	Nitrogen (kg/ha)	Organic matter (tonnes/ha)	Nitrogen (kg/ha)
Tree	159.7	196.4	71.4	116.2
Understorey	0.8	2.6	1.6	3.4
Forest Floor	14.0	87.7	13.5	45.6
Soil (0-75 mm)	33.5	667	31.7	902
Removals in thinnings over 35 years	196	159	0	0

The change in species of plantations is of concern in many areas. Where eucalypts have been planted as exotics there has been the question of their increased leaching capability compared with native vegetation (Calvo *et al.*, 1979, Calvo -Fierros, 1981), but the effects appear to be site specific. However, apart from productivity and different leaching potentials the impact of nutrient accumulation differentials requires assessment. For example, the smooth barked eucalypts are calcium accumulators, noticeably in the bark, and this will lead to rapid redistribution of calcium from soil to vegetation. Based on calcium concentration data only (Table 9) replacement of native *Eucalyptus obliqua* or *E. sieberi* with the exotic *Pinus radiata* would have little effect, however, replacement with *E. grandis* would lead to high accumulation of calcium. Turner and Gessel (1990) reported a comparison of peak *P. radiata* and *E. grandis* calcium uptake being 40 and 120 kg/ha/yr respectively.

Table 9. Calcium concentration (%) in tissues of four forest tree species.

Species	Foliage	Bark	Sapwood	Heartwood	Reference
Pinus radiata	0.25	0.31	0.05	0.06	Authors data
Eucalyptus grandis	0.48	1.94	0.06	0.04	Turner & Lambert (1983)
Eucalyptus obliqua	0.39	0.45	0.03	0.09	Attiwill (1980)
Eucalyptus sieberi	0.48	0.04	0.04	0.02	Authors data

The specific accumulation of nutrients and their removal in fast growing crops is readily replaceable by the use of fertilizers. An appropriate nutrient monitoring system is required, the more so as yields are increased or rotations shortened.

Apart from timber yields plantation managers need to consider the management in relation to other products such as water. In many areas plantations are located in major water supply catchment areas and both water yield and quality are of concern. Quality effects, such as sediment, can be maitained at low levels with suitable roading patterns and use of riparian steps. Water yield will be affected where there is a major change in vegetation type (grassland to forest) or a major increase in productivity over a significant portion of the catchment. In the case of conversion from grassland to forests declines in yield of 40% may be anticipated (Burch *et al.* 1987). Conversion of a scrub area in South Africa to a *Eucalyptus grandis* plantation over most of the catchment area led to a decline in water yield of 48% of mean annual streamflow three years after planting (Bosch and Bosch, 1989). This supports work on changes from grassland to pine plantations (e.g. Bosch and Hewlett, 1982; Van Wyk, 1987) but this change is not expected when changing forest to different forest species. Changes from grassland to pine have reduced to concentrations of nitrate and phosphate in runoff waters, this reducing entrophication effects (Cooper *et al.*, 1987).

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GUIDELINES FOR FOREST SOIL INVESTIGATIONS IN AUSTRIA

Walter Kilian and Franz Mutsch

Head of Institute and Senior Research Officer
Institute of Site Research

Federal Forest Research Station
Vienna, Austria

FDC: 114--010

SUMMARY

The amount of pedological data is rising dramatically, but the diversity of methods employed impede a lucid communication between scientists and the evaluation of large scale surveys. Therefore a standardization or at least a review of the main soil analytical methods used in the world would be an important task for IUFRO. To stimulate such an acitvity, the Austrian "Guidelines for Forest Soil Investigations" are presented as an example on national basis. Many of the methods mentioned there have also been accepted by the National Standards (ÖNORM). The guidelines regard 3 levels of investigations, according to the actual main scopes. They deal with field description sampling and soil analysis.

Keywords: soil analysis, sampling, soil monitoring, standardization

ZUSAMMENFASSUNG

Die Zahl bodenkundlicher Daten steigt derzeit sprunghaft an. Die uneinheitlichen und oft nicht einmal zitierten Methoden machen jedoch eine internationale Verständigung und flächenübergreifende Auswertung dieser Daten schwierig oder unmöglich. Die Vereinheitlichung oder zumindest Dokumentation der wichtigsten in der Welt angewandten Methoden zur Bodenuntersuchung scheint daher eine dringende Aufgabe, welche die IUFRO wahrnehmen sollte. Als Anstoß dazu und als Beispiel auf nationaler Ebene werden die österreichischen Richtlinien zur forstlichen Bodenuntersuchung vorgestellt. Ein Teil der darin festgelegten Methoden wurde auch in die Österreichischen Normen (ÖNORM) aufgenommen. Die Richtlinien behandeln 3 Intensitätsstufen der Bodenuntersuchung, entsprechend den derzeit wichtigsten Fragestellungen und umfassen die Bodenbeschreibung im Gelände, die Probenahme und die chemische Analyse.

Stichworte: Bodenanalyse, Probenahme, Erhebungsnetze, Standardisierung

1 INTRODUCTION

The literature on forest soil investigations has become really vast up to now. The methods applied however, are varied and numerous, and no agreement on this regard has been found until now. Due to this diversity, results of other authors cannot be discussed or understood sufficiently, as the analytical methods used are often not even mentioned in the publications. In a complex system, like forest soils, analytical data are mostly indirect conventional digits, which give a sense only in connection with the pertinent method. Some standardization or at least a comparative review of the main analytical methods used in the world, are needed urgently.

This need for standardized methods applies particularly to regional or national surveys. A few years ago the interest of forestry in soil analysis was restricted to local investigations and subject to a few spezialised scientific organizations. In recent times, however, the demand on forest pedological analysis increased dramatically due to the problems of forest decline and increasing environmental consciouseness. Various activities of public and private institutions on soil conservation and amelioration have recently been sprouting even those who never had dealt with forest soils before. Numerous analytical procedures are being applied and it should be suspected that comprehensive evaluations of all these data particularly the comparision of periodically repeated surveys will become impossible.

For this reason the Austrian Soil Science Society developed in co-oporation with all relevant institutions, guidelines for the serial investigation of forest soils, encompassing field description, terminology, sampling and laboratory analysis. (BLUM et al 1986, 1989).

A greater part of these methods and classifications are going to be introduced into the Austrian National Standards (ÖNORM).

1.1 Scopes of Soil Investigation - Levels of Intensity

The guidelines consider three levels of investigation, according to the main current objects:
.Routine recommendations for amelioration and fertilization
.Large scale representative surveys
.Intensive studies on permanent plots

1.1.1 Amelioration and fertilization

The aim is to assess soil quality and fertilizer requirements without great efforts. Nonspecialized forest personnel should be able to collect samples themselves without special tools. The analysis should be expeditious and inexpensive. There are, however, some problems, restricting the suitability of simple agrochemical tests. For many decades these testing methods have been used with more or less success in agronomy to predict nutrient deficiencies and fertilizer requirements. They were calibrated to a great number of field experiments with agricultural crops, compared with harvest losses and adequate threshold values have been worked out.

The same methods used in environmental or forestry research, however, showed no satisfactory results. Apparently there existed no correlations with tree growth and no reasonable threshold values.

This is obvious, as both the uptake capacity of trees and the features of forest soils are quite different from those in agriculture, to which the test methods have been adjusted.

But there are also further, more fundamental differences between arable soils and forest ecosystems: Most ligneous species have adapted themselves during their evolution to poor, acid soils by their capability to accumulate the little amounts of continuous weathering or airborne nutrients. A great part of these nutrients is stored in the biomass and turning over in a quick cycle of litterfall, decomposition and re-uptake. Therefore the stock of "available" nutrients in the soil is less essential. It may be small even in well growing stands and is subject to seasonal variations and changes during the stand developement. Analytical data of this amount might be nothing but an unspecific snapshot.

As a result soil analysis can contribute essentially to the diagnosis of nutrient status, together with an extensive stand- and site description and foliar analysis. It is, however, more adequate to inform about the general soil condition, the biological activity and conditions of nutrient cycling. Figures like C:N-ratio or exchange capacity are valuable pointers. Also disturbances of base saturation, high deficiencies of K, Mg or Ca and toxic surplus of (heavy) metals can be found. A plain calculation of nutrient supply, however, particularly of N and P, is not possible.

1.1.2 Large scale representative surveys

The purpose of such representative surveys is to give a regional overview on soil/site conditions and their changes by periodical observation. Preferably it is layed out as a grid of observation plots. Volumetric sampling is possible only in the forest floor. It can not be realized universally for the mineral soil of all grid points, owing to the stone content and other obstacles. Informations on state or trend of a distinct single point are mostly not possible rather than those of greater areas. For this purpose a pretentious statistical design and a highly standardized survey is necessary.

1.1.3 Intensive studies on permanent plots

Such plots are used to examine the developement of soil properties (or of the entire ecosystem) over longer periods and to detect cause-effect relationships on a distinct point. The observations there must be as extensive as possible. A great number of replications of samples and single analysis is necessary to ensure sufficient statistical security. On the other hand the sampling procedure should not disturb the experimental plot.

2 FIELD DESCRIPTION

The soil is closely integrated within the forest ecosystem. It must not be regarded as isolated. A sound assessment of soil requires a joint site examination including a site- and soil desription in the field, vegetation, stand- and increment studies. Permanent research plots should be selected carefully with regard to the homogenity of the site. Monitoring plots should amount 400 to 2500 m^2 and avoid stagnous wet areas, where uncontrolled transformations occour.

2.1 Description of Site and General Soil Features

2.1.1 Location:

.District, community, enterprise
.Coordinates of the national reference grid using the topografic map 1:50 000 (accuracy 25 to 50 m) or larger
.Plot number and number of soil samples

2.1.2 Relief

.Elevation in m, from the map 1:50.000 (contour intervals 20 to 10 m) or with altimeter
.Aspect by 8 cardinal points
.Slope gradient in percent
.Landform (physiografic position, meso-relief): landforms with more than 3 m vertical extent. With regard to EDP 19 defined terms are distinguished such as crest, upper slope, terrace, alluvial fan, blockfield.
.Lateral and vertical extension of the landform in m
.Microrelief (landforms smaller than 3 m vertical extent): smooth, grooves, furrows, ridges, etc. (standardized codes)

2.1.3 Hydrology:

.Surface water: balanced flow, predominant runoff or inflow
.Groundwater: depth under surface, seasonal fluctuation of the table
.Subsoil runoff water
.Stagnant water: predominant wet or dry period, balanced
.General water regime estimated in 7 classes: dry, moderately fresh, fresh (no deficit and surplus during the growing season), very fresh, moist, wet

2.1.4 Geology:

.Bedrock
.Cover layers: shallow fine sediment layers, different from parent rock, such as eolian sands, shallow loess layers, fossil soil residues
a) According to geological map; characterizes the general geological condition of the sample area but needs not correspond with the bedrock under lying right the profil pit. Also thin layers of loose sediments may be neglected.
b) Additional field diagnosis; it may differ from the geological map. Description and a numeric code for data base use are given.

2.1.5 General soil features

.Soil depth: depth from the mineral soil surface to bedrock or any restricting layer
.Soil type according to the national classification (FINK 1969); codes for standardized groups are used additionally.

2.1.6 Vegetation:

.Ground vegetation. If possible a correct floristic relevee with regard to abundance and dominance of every species.
.vegetation types: For practical purposes vegetation types have been established, a characteristic combination of dominant species such as: Oxalis-type, Vaccinium-Avenella-moss-type etc. They are a good indicator for the temporary surface soil condition (humus, surface compaction, light exposure etc.). A system of 24 basic types with sample possibilities of subdivision is used in forest inventory (Anonym 1981), site survey and for site date base in general.
.Stand description: tree species, age, dominant height, stand density, stand structure, canopy, stand damages. A stand description is necessary as some soil features react quickly on changes of the stand (pH, C:N-ratio).

2.2 Soil Profile Description

The profile description is carried out at the face of a profile pit, using a standard form and codes. Horizons are noted according to the classification of the Austrian Soil Science Society; for humus layers also with reference to v. ZEZSCHWITZ (1979): O, A, B, C, E; l, f, h, g, o, r, s, t like FAO system; additionally D (substrate not involved in soil developement), P (penetrated stratum), S (inpermeable body of Pseudogley), G (Gley), T (peat), e, rel, p (tillage), inf, ca.

Humus is described extensively. The current system of humus description and classification is not yet fit to charactrize this important compartment of the forest ecosystem sufficiently. It is planned to start some research on this subject in the near future.

Mineral humus horizons are described in detail: The indices for subhorizons Ai, Ah, Ahe, Aeh, Ae indicate the degree of percolation; Abiog, Ainf (infiltration) is optionally used. Humus types are deduced from the whole humus profile: Mull, moder, mor, peat with subdivisions in hydromorphic, xeromorphic, mull-moder etc.

For each soil horizon the following features are described:

2.2.1 Forest floor (more than 30 % organic matter)

.distinction of subhorizons (Ol, Of, Oh)
.thickness of subhorizon
.Boundaries (abrupt, gradual)
.Materials, content of fine material
.degree of decomposition

.character: fibrous, sticky, greasy
.consistence: loos, friable, glued, matted, massive-brittle, firm
.rooting

2.2.2 Mineral soil

.Identification of Horizons
.Depth and thickness: measured from the surface of mineral soil
.Boundary: distinctness sharp (<2cm), clear (2-5cm), gradual (5-10), diffuse (>10cm); form smooth, wavy, pocketlike, broken
.Particle size classes (texture): 12 classes defined by texture triangle (sand, silt, loam, clay and combinations); field assessment by finger test; for sand additionally: fine, medium, coarse
.Content of coarse particles (stoniness): Quanitity estimated in 6 steps; shape (rounded, angular), optional plated, oriented etc.; size (2-63 mm, 63-200 mm, >200 mm)
.Colour: according to MUNSELL Soil Colour Charts, earth fresh or wet, surface of aggregates or rubbed soil
.Noddles, bands, concretions: contrast, abundance, size, nature (weathering, carbonate, iron, humus, bleached...)
.Carbonate: 4 steps estimated, using deluted HCl
.Structure:
shape: strucureless loose (single grain) or massive (compact)
peds: platy, columnar, prismatic, subangular blocky, angular blocky, crumb, granular; other aggregates: clods, soil fragments
distinctness: distinct, undistinct
size: fine, medium, coarse
.Porosity: size and abundance are visually estimated using charts; fissures, crevices and other cavities are described separately.
.Rooting: number of fine roots (<2 mm) per dm^2 in 6 classes, estimated at the profile face, in adequate distance from stumps.

2.2.3 Set of field parameters for the three levels of investication:

	mineral soil			forest floor		
	fertil.	survey	perm. plot	fertil.	survey	perm. plot
diagnostic horizon	+	+	+	+	+	+
depth and thickness	+	+	+	+	+	+
boundary			+			+
material				+	+	+
particle size class	+	+	+			
stoniness (particles >2mm)	+	+	+			
colour		+	+			
mottling, concretions	+	+	+			
carbonate content		+	+			
soil structure			+		+	+
consistence					+	+
porosity		+	+			
rooting		+	+			+
humus content			+			

3 SOIL SAMPLING

3.1 Procedures

Even for simple tests, such as for fertilizer recommendations, samples must be collected carefully. The spatial variability must be overcome with a sufficient number of samples, at least by forming one composite sample. In monitoring plots the sample points must be durably marked to ensure future sampling from undisturbed soil profiles.

For temporal comparisons, studies on element cycles or net balances; the analysis of layers with distinct depth and not of diagnostic horizons has proofed to be the only appropriate method, in spite of all pedological conventions. Samples from diagnostic horizons can be taken additionally.

If a sample collection on a volumetric basis is not possible, the bulk density should be estimated. Depending on purpose and demand on accuracy several procedures are recommended:

3.1.1 Volume proportional samples

.Forest floor: area proportional samples cut with a steel frame, 30 x 30 cm.
.Mineral soil: cores are taken with a teflon-covered steel tube. Practicable only in not too sandy or stony soils; preferable for monitoring element quantities and fluxes, when a greater number of samples from one plot is to be taken and also to minimize the disturbance of permanent experiment plots.

3.1.2 Disturbed bag samples

They are taken from a profile face adequate for analysis of concentrations and features of single horizons, not too many samples reqired, and in soils which do not allow core sampling. No special tools are required. Calculation of quantities and balances is not possible.

3.2 Application

3.2.1 Fertilizer recommendations

.Forest floor: bag- or steel frame samples (3 samples from at least 1 point)
.Mineral soil: bag samples from >=3 profile pits, at least 30 cm depth; subsoil by auger (5-10 samples each) from the bottom of the pit. The samples are combined to one composite sample from each layer (0-10 cm, 10-30 cm, 30-50 cm). These strata will include most of the rooting zone.

3.2.2 Representative surveys

As above, but layers from 0-5, 5-10, 10-20, 20-30 and 30-50 cm, and if possible >50 cm depth, down to the full depth of geochemical weathering.

3.2.3 Permanent plots

- .Forest floor: area proportional samples 30 x 30 cm; 1 to 5 samples from 10 subplots.
- .Mineral soil: soil cores, cut into samples from standard depth (or horizons additionally). With regard to the soil variability the minimum number of samples should be as follows: From 0-5 and 5-10 cm 10 subplots, from 10-20 and 20-30 cm 5 subplots, 3 cores each; from 30-50 cm an deeper 5 subplots, 3 cores each or 5-10 auger samples.

The samples from each subplot are analyzed separately as replications for statistical examinations.

4 SOIL ANALYSIS

4.1 Sample preparation:

To keep the efforts of sample handling reasonable, most analytical methods in use are adapted to air-dry samples. The bulk samples are dried fast but carefully, at room temperature, then gently crushed and sieved to 2 mm fine earth. Volumetric samples are weighed before and the gravel retained after the sieving. For the determination of total contents with low initial weight (<500 mg - N,C) the fine earth is ground to powder size.

For scientific exact determinations the water content of the analyzed air dry sample is determined (105 ^{o}C) for conversion into oven dry material. For the calculation of analytical data into amounts in kg/ha at least an estimate of the bulk density is necessary and the content of coarse material must be taken into account.

4.2 Analytical methods

The aim of the chosen methods is to determine as many soil parameters as possible with reasonable analytical efforts, suitable for great series, but high scientific accuracy. The international compatibility was taken into account, too. Emphasis is layed on internal control and permanent interlab comparisions. For all the mentioned methods in the following a detailed description of the procedure is given in the cited guidebook (BLUM et al. 1986).

4.2.1 pH-value

It is measured conventionally in a suspension with 0,01 m $CaCl_2$ and in H_2O. The ratio soil/solution is 1:2,5 for mineral soils and 1:12,5 for forest floor. From the difference of both measurements an amount of protons can be calculated. This is a practicable value to compare the actual and potential acidity, giving a certain idea of actual acidification processes.

4.2.2 Total N

Determination by Kjeldahl method. This method does not comprise nitrate-N, yet this hardly makes a difference for the total N content in most forest soils.

4.2.3 Total and organic C

Determination of total carbon as CO_2 by dry combustion in oxygene flow and measurement of CO_2 by infrared-absorption. Eventually existing carbonate is substracted. The relative inacurate determination of carbonate does not affect the calculation with regard to the factor 0.12 (C in $CaCO_3$). The humus content is calculated by the conventional factor C x 1.724.

The determination of organic matter by wet oxydation is incomplete and inappropriate for forest soils with higher humus content.

4.2.4 Carbonate

The conventional volumetric method with HCl, according to SCHEIBLER, is considered to be sufficient. The carbonate content is reported as $CaCO_3$. The possible contribution of Mg- or Fe- carbonate is to be regarded for interpretations. The slow and possibly incomplete reaction of $MgCO_3$ with room temperature can be overcome with fine ground samples.

4.2.5 "Stock" of nutrient elements and heavy metals

With regard to the disappointing results with the common extraction methods for "available" nutrients, as mentionend above, the analysis of the "reserve pool" of nutrient elements from an extract with hot concentrated acid has been prefered for decades. This treatment describes about those parts of elements, which will be reliesed from weathering of parent minerals over a longer period; it is particularly suited to characterize the permanent nutritional quality of a site. In the surface organic layer the determination of total K, Ca, Mg, and Al, Fe, Mn may provide valuable informations on the degree of acidification and the nutritional status.

For many elements and soils this fraction comes very close to the total content. The procedure, however, is more rapid and simpler than fusion or HF-decomposition.

As agent a mixture of nitric and perchloric acid in relation 5+1 is used. For forest soils with high humus content, particularly of organic surface layers this mixture has proved most appropriate because of its high capacity to decomposite organic material. The data received are comparable quite well with those from extracts with aqua regia, commonly used in the analysis of sewage sludge, or from hot hydrochloric acid (FIEDLER et.al. 1965), used previously at the Austrian Forest Research Station for forest soils (KILIAN 1988).

The decomposition is carried out at 180 ^{o}C, favourably applying an apparatus with exhausting device and programmed temperature control. For volatile elements a backflow condenser system, for AAS-determination of Hg also a Hg-hydride device is additionally necessary.

The analysis of elements is carried out with AAS, ICP and polarograph respectively. The following elments are determined from this extract:
.macro elements: P, K, Ca, Mg, Fe
.micro nutrients, toxic elements: As, Cd, Co, Cu, Hg, Mn, Mo, Ni, Pb, V, Zn
.in the forest floor additionally: Al

4.2.6 Exchangeable cations - cation exchange capacity (CEC)

As to determine a kind of "counterpoint" in a chain of solubility the exchangeable cations are the obvious choice, as an internationally accepted parameter. The cation exchange capacity and base saturation are highly meaningful criteria for the nutritional status, the buffer capacity and the stability of the soil. - The generally suggested leaching procedure, however, is unpracticable for greater series and thus has been substituted by an extraction method. Extraction agent is 0,1 m $BaCl_2$-solution; unbuffered for soils with pH 6,5 and lower, buffered for calcareous soils and those of more than pH 6,5 with triethanolamine. This agent has been suggested already by JACKSON (1960). The effectiveness of bivalent ions in replacing exchangeable cations such as Ba is much higher than the usually employed single valid NH_4-ion. That ensures a more complete exchange of K, and of polyvalent metals like Fe, Al and Mn; that, in its turn allows lower concentrations and thus grants a measurement with less interferences.

The following ions are determined: K, Ca, Mg, (optional Na - this and NH_4 are neglible in most forest soils). In unbuffered extracts (of acid soils) additionally Fe, Al, Mn and H. The cations are reported as mM.Ieq/kg soil. It is also calculated as percentage of the total CEC. The total CEC is calculated from the sum of measured ions and checked by reexchange of consumed $BaCl_2$ with HCl. This determination of exchangeable cations has proved to be reasonable only in mineral soil samples.

4.2.7 Mobile heavy metals

They are determined from the extract with 0,1 m $BaCl_2$ 1:2,5. This fraction, and its ratio to the total content relates to heavy metal pollutions of mineral soils in contrast to the supply from parent material. According to recent results this extract is more appropriate rather than EDTA, which is much stronger and closer to the total content.

It was mentioned already, that particularly P and N nutrition is supplied to a great extent by the continuous transformation of organic matter. Thus a determination of a soluble fraction of P and N has been consciously denied.

4.2.8 Neutralizing capacity

This method is yet under development. It should also contribute to the estimation of acidifacation hazards and of the sensitivity of soils (MEIWES et al. 1984). In batch experiments the equivalents of acids are determined by titration, which react within a given time up to certain pH values. Calcium carbonate as base agent would simulate the effect of liming at best, but the extreme slow reaction makes its use inpracticable. Therefore a combination of $CaCl_2$ and NaOH is suggested. This determination is meaningful only for mineral soil samples, too.

4.2.9 Water extract determinations

A suspension 1+5 is used. This artificial extract of constant soil/water ratio is much more practicable than sampling of soil solution in the field and on the other hand independent from the variability of the soil solution

with time. The electric conductivity, measured with conductometer gives a first information on extraordinary salt concentrations. The determination of SO_4, Cl and F can help to detect pollutions. If necessary also further anions and elements, important from the nutritional or toxicological point of view may be measured. Measurement among others with ionchromatograph.

4.2.10 Total S

Similarly to total C determined by combustion in the oxygen flow and measurement of SO_2 by infrared absorbtion, using an automatic sulfur analysator. The S-determination is carried out only for the forest floor. C:S- and C:N-ratios indicate sulfur pollution quite well (ZUCKER et al. 1986, 1988).

4.2.11 Particle size spectrum (texture)

The soil texture is a superior physical feature qualifying the effect and attitude of most of the chemical properties. On the other hand it is one of the few physical paramameter which can be determined from a disturbed bag sample. After dispersion with sodium pyrophosphate and shaking 6 fractions of the logarithmic scale 2 - 6,3 - 2 are determined by wet sieving and sedimentation.

4.2.12 Set of analytical parameters for the three levels of application

	fertiliz.	survey	permanant plot
pH ($CaCl_2$)	+	+	+
pH (H_2O)		+	+
N tot.	+	+	+
C tot.	+	+	+
Carbonate	+	+	+
perchloric-nitric-acid-extr.:			
P,K,Ca,Mg	+	+	+
Fe,Mn		+	+
Al		f	f
other heavy metals/micr.nutr.		+	+
exchangeable cations ($BaCl_2$)			
CEC		+	+
K,Ca,Mg(,Na)	(+)	+	+
Al,Fe,Mn (only soils pH<6,5)		+	+
heavy metals			+
neutralizing capacity			+
water extract			
conductivity		+	+
sulfate		+	+
other anions and elements			+
S tot.		f	f
particle size analysis		+	+

f = forest floor only

The guidelines described in this paper, should stimulate the review of soil analytical methods also on an international basis. A set of "best" methods will certainly not to be found in the near future. But it would be very

benefical if we could come to an agreement on a set of standard methods, or at least could achieve a directory of the main methods used in the world. This would be a good task of the working party soil chemistry in IUFRO.

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A STRATEGY FOR RESEARCH ON THE MAINTENANCE OF LONG-TERM SITE PRODUCTIVITY

James Peter (Hamish) Kimmins

Professor of Forest Ecology
Department of Forest Sciences
Faculty of Forestry

University of British Columbia
Vancouver, B.C., Canada V6M 1W5

FDC: 180: 62: 945

SUMMARY

Both the social and the biophysical environments in which the world's forest are being managed are undergoing rapid change. It is the responsibility of forest scientists to provide the knowledge needed to understand the implications of these changes for the form, function, diversity, and temporal dynamics of forest ecosystems. This is not sufficient, however. Forest science must also develop practical systems by which resource managers can make accurate predictions about the long-term sustainability or renewability of a wide variety of forest values under a variety of future management and environmental scenarios. This will involve the investment of resources in the development of methodologies that can synthesize existing disciplinary knowledge into landscape-level predictive systems. The balance between reductionist, process-oriented, disciplinary research and multi-disciplinary, integrative research that produces rotation-length or multi-rotation-length "decision support" systems for use by forest managers must change in favour of the latter.

Forestry is under increasing scrutiny around the world, and a public that is often poorly informed about forest ecosystems and their response to management is judging our profession very harshly. Many of their concerns are justified, but many are the result of an inadequate understanding of forests and forestry. It is time for forest scientists to invest more effort in the communication of existing and new knowledge to the public, to politicians, and to schools. Failure to do so may lead to a decline in the number and quality of young people entering forestry and forest science as a profession.

Forest science in the 1990's needs a research strategy that ensures that these needs, responsibilities, and challenges are met. Some suggestions about the nature of such a strategy are presented.

Keywords: Long-term site productivity, research strategy.

INTRODUCTION

The decade of the 1980's has witnessed some remarkable changes that have significance for forestry. In spite of famine, war, and disease, the human population continues to grow, but it is predicted that it will level off between 10 and 11 billion in the next century (Repetto 1987). It appears that communism and other totalitarian forms of government are on the decline and that democracy is on the increase. These political and population trends will probably result in a slow improvement in standards of living and material consumption in the countries concerned. The resulting modernization will undoubtedly ameliorate some of the worst cases of air and water pollution, soil degradation, and ecosystem simplification that have attended the poverty, totalitarian governments, and/or war in these countries. However, if population size and/or material expectations continue to rise, there will almost certainly be increased demands for a variety of values and products from an area of forest that in many cases may be declining.

The 1970's was a decade in which the seriousness of the "acid rain" phenomenon and accompanying "forest decline" was widely recognized. However, in the 1980's "acid rain" began to take second place to concerns about "global climate change" as the most serious long-term threat to the world's forests. Increasing attention has also been paid to the physical soil degradation that sometimes accompanies clearcut harvesting, and concerns about the risk to soil fertility of more intensive biomass production and harvesting, which have been raised periodically since early in the 19th century, are being heard again. The trend towards increased mechanization has been a major contributor to these concerns, but a growing interest in renewable bioenergy as a partial replacement for fossil fuels to reduce the "greenhouse" problem will undoubtedly contribute to the trend towards utilization of more of the biomass at time of harvest, and to the threat to soil fertility and long-term site productivity. The combined effects of environmental change and increased demand from other land uses pose a threat to both the long-term forest land base for timber production and the supply of industrial roundwood from that land.

The change in public attitude towards forestry and the environment that has occurred over the past two decades may contribute significantly to changes in forest practise, and may, in some areas, contribute to the expected reduction in area of forest dedicated to the production of wood products. The "environmental movement" has captured the public's imagination in much of the industrialized world, and is now a major political force. Repeated warnings over the years by ecologists, biologists, forest and agricultural scientists, environmentalists, concerned citizens, and some foresters have successfully communicated the extent and seriousness of the human-induced global environmental alteration to governments and international agencies. The issue of tropical deforestation (conversion of forest to agriculture, hydro-electricity reservoirs, or simply to denuded land) has become a rallying point for the international environmental movement, and the concerns of this group have now refocused on forest harvesting and/or forest management in temperate and boreal latitudes. There have been

inevitable and often uncritical comparisons between tropical forest exploitation and deforestation and temperate/boreal forestry, and the public in North America has loudly condemned forest industry for what they have been led to believe is massive environmental degradation caused by forest harvesting. Accompanying this criticism has been a rapid acceleration in public demands for increased reservation of "old growth" forest, especially of temperate rainforests of giant trees in the Pacific northwest of U.S.A., western Canada, and Tasmania.

The objective of my paper is to examine the relationship between this changing world forestry scene and the organization and conduct of forest science. My thesis is that the balance between traditional, process-oriented, disciplinary research designed to produce knowledge and understanding, and more integrative, cross-disciplinary research designed to produce predictive decision support tools should be adjusted in favour of the latter. The former is necessary and must be continued, but is not sufficient if forestry is to be able to meet the challenges and opportunities of the 1990's and the 21st century. I will conclude the paper by discussing the topic in the context of a strategy for long-term site productivity research. This is a philosophical, "ideas" paper, and is largely unreferenced.

THE NATURE OF TRADITIONAL SCIENCE AND ITS IMPACT ON THE CONTRIBUTION OF FOREST SCIENCE TO FORESTRY

Science is largely concerned with understanding living organisms, the local, regional, and global abiotic environments in which they exist, and the interactions between them. As the body of human knowledge has expanded exponentially, the advancement of knowledge has inevitably and necessarily become organized into disciplines, employing process-oriented, reductionist research. Some branches of the basic sciences, such as ecology and soil science, have struggled to remain holistic, but even these scientific endeavors have been constrained by the requirement of the "Scientific Method" that knowledge can only advance as a result of the development of testable and falsifiable theories, or predictions therefrom (hypotheses). In general, though not necessarily, this has been interpreted to mean rather simple (ie. "reductionist") hypotheses, since complex hypotheses, or the predictions thereof, are difficult to test experimentally. This has continually drawn these inherently integrative, interdisciplinary sciences towards a more reductionist, disciplinary approach to research.

A product of forest science over the past half century has been a significant increase in our understanding of many aspects of forest ecosystems and their response to management and environmental change. Much remains to be discovered of course, but there is now a formidable and rapidly growing catalogue of known facts. Our libraries are bulging with the accumulated knowledge, and it is becoming increasingly difficult to keep up-to-date with new research findings, except in increasingly narrow subjects. Disciplinary, process-oriented science has been well served, but it is reasonable to enquire as to how useful

the results of much of this research have been to the practise of forestry.

My perception is that forest science has tended to address the needs of forest science more than the needs of forestry. Much, though certainly not all, of the forest science research in the past two decades in North America has been influenced by the policies of granting agencies (short-term funding) and the career requirements of junior scientists and academics (to produce frequent publications). These factors, together with the necessity for scientific rigor, have resulted in a distinct focus on short-term, process-oriented research.

THE CHALLENGE TO FOREST SCIENCE IN THE 1990's

Advancing our understanding of the biotic and abiotic components and processes of forest environments is an unquestionable prerequisite for the advancement of the practise of forestry. There will always be a need for traditional, disciplinary forest science. But while this type of research is necessary, it is not sufficient as the basis for improved management of forested landscapes. Advances in forest management have lagged far behind the body of scientific information that is accumulating on library shelves. The reason? In many cases, it is because the research was designed to address scientific questions rather than management questions. Much of the research was conducted over spatial and temporal scales that are scientifically valid, but are very different from those that must be dealt with in forest management (Baskerville 1987). In other cases, it is because foresters need to be able to predict, more than they need to understand. Prediction may require understanding, of course. But it is the ability to chose between alternative courses of action in silviculture and management that is so important to the practise of forestry, and this requires prediction of the rotation length consequences of the choices. Forest science has in general contributed less to our ability to predict the response of forest ecosystems to management and environmental change than to the understanding of the processes involved.

The challenge that forest science must meet in the 1990's is to continue to conduct research to fill critical knowledge gaps, but to match this activity by the development of predictive, "decision support" tools. These tools, which may take a variety of forms (including maps, field management guides, "decision trees", "expert systems", computer simulation models, and "management games"), depend on, and integrate the knowledge created by, the more traditional types of research. However, the two activities must be closely coordinated if the management-oriented research on the development of predictive tools is to be able to utilize the products of traditional process-oriented research. One critical research need is thus to increase the investment of research resources into the synthesis of existing and new disciplinary knowledge into practical systems of prediction. These systems are needed by forest managers to predict the consequences of alternative management actions under anticipated patterns of environmental change. Another need is to develop mechanisms that foster the interaction between

researchers who are developing the prediction systems, and those conducting the basic science on which these systems must be based. There is a need for the development of research groups that include the appropriate basic scientists working in cooperation with the researcher(s) who are developing the predictive tools, who is (are) in turn in close contact with the potential users of the tools.

An obvious concern over such a strategy is that focussing research on practical questions will inhibit basic, "curiosity" research, which is widely recognized to be essential to the long-term success of research programs. My response to this concern is that basic forest research should continue, but that it be conducted in areas that relate to practical problems, and in a manner that contributes to the development of practical methods of making better forest management decisions. We are at a point in human history where we simply do not have the luxury of ignoring environmental problems. Science must certainly continue to contribute to our storehouse of basic knowledge, but must increasingly focus this acquisition of new knowledge in a manner that addresses the needs of environmental management.

A STRATEGY FOR LONG-TERM SITE PRODUCTIVITY RESEARCH

The need for a refocusing of research strategies is probably as important in the area of long-term site productivity as it is for any other topic in forestry. The problem is that because the questions are long-term and relate to the functioning of the entire ecosystem, they often cannot be addressed adequately by disciplinary, process-oriented research on its own.

The ideal way to make predictions about the long-term effects of management on site productivity is to have well-documented empirical evidence of these effects. Unfortunately, such experience-based predictions can rarely be made for lack of appropriate empirical data. In Canada, most forestry still involves the harvesting of previously unmanaged forests, and although many of our young second-growth forests, once adequately regenerated, appear to be growing as well as, or better than, the forests they replaced, there is no more experience-based evidence that this productivity will be maintained in the future than that it will not, even without climate change.

In the absence of appropriate experience-based predictors of the sustainability of long-term site productivity, there are two obvious things we need to do: 1, to establish an appropriate network of well-documented, long-term field trials to examine the consequences of such practices as clearcutting, whole tree harvesting, slashburning, and the accompanying soil compaction, erosion, or loss of organic matter and nutrients, and 2, to develop knowledge-based predictors for use until we have acquired the necessary experience-based knowledge from the long-term field trials.

A lot of experience-based knowledge can certainly be gleaned from chronosequence and retrospective studies, in spite of the significant

difficulties involved in both these research approaches (see papers in Dyck and Mees 1990). "Expert systems" constitute another way of synthesizing experience into a decision-support framework for management use. And long-term experience from areas such as Europe and Scandinavia that have already had a history of many rotations of tree crops can be used to make qualitative assessments of the probable long-term consequences of stand-level management in areas that lack such experience. However, the difficulties of extrapolating experience between areas that are ecologically very different, and the general paucity of experience on which to develop expert systems for use in many aspects of forest management, suggest that there is still an urgent need to initiate programs of long-term field trials, and to develop knowledge-based predictors.

The development of knowledge-based, long-term, ecosystem-level predictors of growth, yield, and other aspects of forestry requires a program of research to gather the appropriate calibration data. Traditional process-oriented research may provide the necessary data, but unless the two activities are well coordinated, there is a significant risk that appropriate data will not be collected.

With the growing concern about the environment and the sustainability of resources, there are many new research projects focussing on the maintenance of long-term site productivity. Unless these programs are conducted under an explicit strategy that ties knowledge - generating, process-based basic research to the development of long-term predictive decision support tools, there is a significant risk that this research will, like many research projects in the past, serve science more than it will serve forestry and society in general. Considering the urgency of the questions of resource sustainability and environmental deterioration, this in unacceptable.

Based on the above discussion, a strategy for long-term site productivity research should have three major components: 1. The establishment of well-monitored long-term field trials to provide well-documented empirical evidence of long-term impacts of management. The results will provide verification data for predictive, decision-support tools. 2. Continued research on basic ecosystem processes, conducted in conjunction with the long-term field trials. The results will provide the knowledge and calibration data needed for the development of predictive decision-support tools. 3. The development of a variety of predictive decision-support tools. These should include computer simulation models, field guides, decision keys, and expert systems. These should be developed from a combination of existing field experience and data on processes, and the results of the other two components of the research program as they become available. All three components of this research program should be closely integrated.

COMMUNICATION OF RESEARCH RESULTS TO PUBLIC, POLITICIANS AND SCHOOLS

Most forest scientists communicate mostly with other forest scientists. Communication between forest managers and scientists has

traditionally been poor, but has been improving as public pressure has forced foresters to be more accountable for their management of the environment, and as they seek more believable evidence about the sustainability of yield and the soundness of their silvicultural investments. Research strategies to develop decision-support tools should facilitate a continuing improvement in this level of communication.

Foresters and forest scientists have generally been singularly poor about communicating with the public and the politicians who ultimately determine the legal and policy environment within which forests are managed. The forestry profession has repeatedly "shot itself in the foot" by failing to monitor and respond to changing public opinion, and failing to develop meaningful and effective communications with the public over contentious issues. This situation is changing rapidly, as forest companies perceive that public pressure groups are increasingly determining what does and does not happen in the forest. The quality and extent of efforts by professional foresters to explain to the public the basics of good forest management has increased dramatically in western North America in the last few years. However, much remains to be done in this area, which now constitutes a legitimate area of forest research. Forest scientists can contribute to this important communication activity by presenting their research findings to the print and television media, on video, and by the development of educational computer "games" that demonstrate in a scientifically-sound manner the principles and long-term consequences of forest management. Such educational tools can be derived from the predictive decision-support tools which forest scientists should be developing (eg. Kimmins 1986, 1988)

CONCLUSIONS

Forest science has a double responsibility: to increase our understanding of how forest ecosystems work, and to improve our ability to predict, over spatial and temporal scales that are meaningful in management, how these ecosystems will respond to management and human-induced environmental change. In the past, science has discharged the former responsibility more successfully than the latter. Considering the predicted changes in human numbers and global climate over the next 100 years, there is an urgent need to develop appropriate tools by which to make believable predictions about the long-term impacts of forest management. The successful development of such tools will require some reassignment of resources from basic research to the development of appropriate predictive systems, and the coordination of basic research with this particular type of applied research to ensure that the former provides the necessary knowledge and calibration data for the latter.

Considering the rapidly-changing public attitude towards and concern for the environment, forest scientists also have a responsibility to develop educational materials that will communicate to the public our current understanding of how forest ecosystems respond to management. Public education is important so that the public pressure

on politicians is based on scientifically-sound, informed opinion on a variety of issues related to forestry. Computer-based decision-support tools developed for forest managers can be modified to render them suitable for application in high schools and for use by concerned citizen groups.

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SHORT ROTATION PLANTATIONS IN CENTRAL EUROPE: NUTRITION AND INFLUENCES ON SOIL FACTORS

K.E. REHFUESS, I. ROSCH and F. MAKESCHIN

Chair of Soil Science
University of München
Amalienstraße 52
8000 München 40/FRG

FDC: 238: 237.4: 181.65: 114.5/.6: (4)

ABSTRACT

A short-rotation experiment with 4 poplar and willow clones was established 1983 as part of an integrated project in north-eastern Bavaria/FRG. After 5 years, balsam poplars and aspen showed an accumulated average shoot biomass (without leaves) of 27-30 t DM/ha, while Salix viminalis had produced 20 t. Production on wet soils was lower than that on the well-drained sites. Fertilization with N increased the biomass production of balsam poplars and Salix only during the 5th growing season, while fertilization with P, K and Mg did not cause any significant growth effect. Comparative analyses of soil samples from 1983 and 1986 did not reveal any significant changes of soil chemical properties. The concentrations of NH_4- + NO_3-N in the soil solution decreased between 1984 and 1987. Changing from agricultural to forest management resulted in a significant increase of earthworms (Lumbricidae), harvestmen (Opilionida) and woodlice (Isopoda), and a higher diversity of the ground vegetation.

1. INTRODUCTION AND OBJECTIVES

Afforestation of agricultural areas as contribution towards solving the problems of surplus food production is currently under intensive discussion in the European Community. In converting arable to forest land the merits of conventional afforestation are weighed against those of cultivating fast growing trees in short rotation. Since 1983 experiments are carried out in north eastern Bavaria within the scope of an interdisciplinary integrated project. Site and nutritional effects are examined and the ecological effects relating to the biomass production of fast-growing poplars and willows are investigated.

2. SITE AND EXPERIMENTAL PROGRAMME

The experiment was established in 1983 on a site previously used as arable land. The Chair of Soil Science test area is divided into an upper part

(brown earth and pseudogley soils) and a lower area (mainly pseudogley and gley soils) where the following aspen, balsam poplar and willow clones are tested: Populus tremula x P. tremuloides cv. Astria, Populus trichocarpa cv. Muhle Larsen, Populus x interamericana cv. Rap, Salix viminalis clone 722/51. One year after planting, a fertilization experiment (N, P, K, Mg, Ca) was started. The site conditions and the experimental treatments are described in detail in (1).

3. RESULTS

3.1 Development of Biomass Stores 1983-87

Accumulation of above-ground biomass was limited in the first two growing seasons by weed competition and then rose steeply from 1985 until 1987 (Fig. 1). In the 5th season both balsam poplars (Muhle Larsen and Rap) with average biomass stores of 30 and 28 t DM/ha (DM = dry matter) respectively were already slightly above the comparative values for Astria with 27 t DM/ha; the willow showed statistically significant lower dry matter stores (20 t/ha).

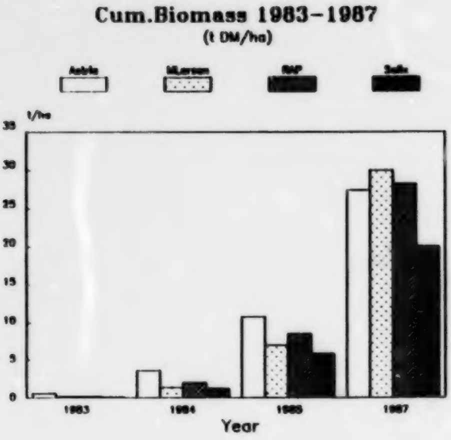

Fig. 1. Cumulative average shoot biomass storage (t DM/ha) of poplar and willow clones during the frist rotation period 1983-87

3.2 Effect of Fertilization and Site on Growth and Nutritional Status

The aspen Astria so far did not show any significant response to fertilization (Fig. 2). In contrast, with Muhle Larsen, Rap and Salix N fertilization alone and combined with PKMg increased production of shoot mass. P, K and/or Mg fertilization alone hitherto had no effect on growth. Irrespective of the fertilization regime, the more wet area showed significantly smaller biomass stores than the better drained, more elevated sites; the deviation was greatest for Muhle Larsen and Salix viminalis (42 %), followed by Astria (24 %) and Rap (23 %). Foliar N, P, K and Mg levels for poplars and willows reach or even exceed those recommended for conventionally grown poplars (Fig. 3) even on the control plots. Since 1987, N-fertilization has led to raised N contents in foliage of Muhle Larsen and Rap.

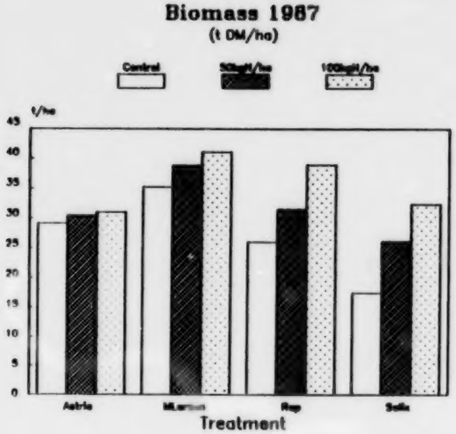

Fig. 2. Shoot biomass storage 1987 (t DM/ha) of poplar and willow clones after five years growth of the first rotation period, differentiated by N-fertilization (kg/ha·year)

3.3 Effects on Soil Fauna

Conversion from arable to forest management significantly increased the density of the earthworm population in the soils (Fig. 4). So far, the use of fertilizer had no effects on the earthworm fauna. A marked increase in the number of young individuals is noticeable in the age-structure of the populations as compared with neighbouring arable fields. Evaluation of pitfall-traps in autumn 1986 showed a decrease in activity density of Coleoptera under poplar in comparison with fields. The species found were almost exclusively ground beetles (Carabidae). Use of fertilizer appeared to have had no effect neither on the species present nor on population

structure. Spiders (Araneida) were less abundant under poplars. In contrast activity densities of harvestmen (Opilionida) and woodlice (Isopoda) were always significantly higher in the poplar areas than in the fields (Fig. 5).

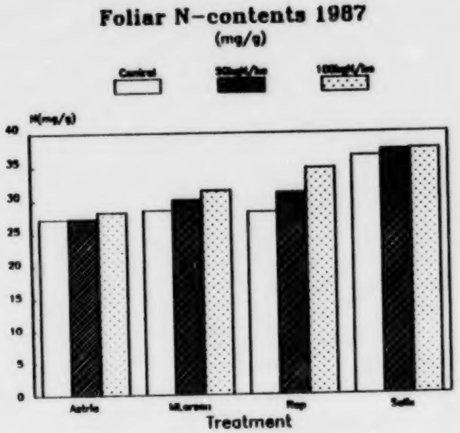

Fig. 3. Foliar N-contents (mg N/g DM) 1987, differentiated by N-fertilization (kg/ha·year)

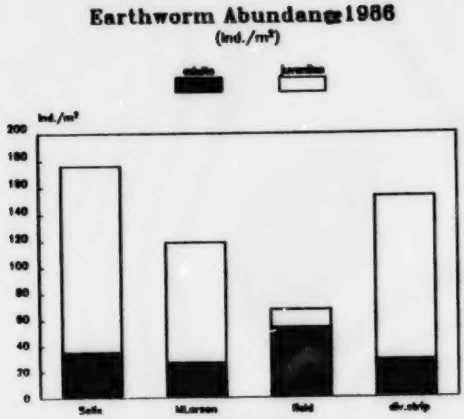

Fig. 4. Abundance of earthworms (autumn 1986) in the unfertilized control plot of Salix and Muhle-Larsen, in the arable field and in uncultivated dividing strips

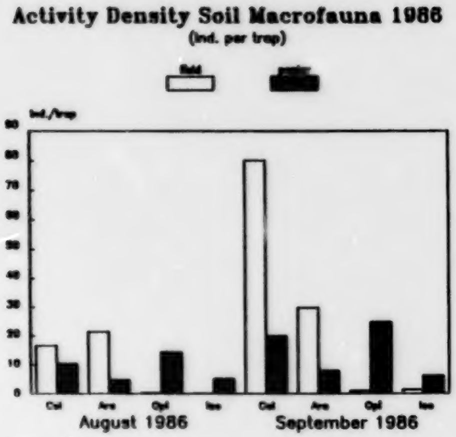

Fig. 5. Abundance of Coleoptera, Araneida, Opilionida and Isopoda 1986 at the arable field and under poplars (control plots of Muhle Larsen)

4. DISCUSSION

After establishment of the plants during the first two years the poplar clones tested fulfil the expectations with regard to high biomass production. The average annual shoot mass growth in the two years prior to harvest reached 8.4, 9.8 and 11.5 t per ha with Astria, Rap and Muhle Larsen, respectively. According to the experience of our project partners (3) even higher growth rates are to be expected especially in the 2nd and 3rd rotation. In 2-year rotations in the Weser Valley Muhle Larsen achieved 13, 14 and 20 and Rap 21, 19 and 46 t annual dry shoot mass production per hectare in three successive rotations (3). From Canadian experiments (2) growth data of up to 20 t DM per ha and year for Rap are reported.

In contrast, during the first 5-year rotation Salix viminalis 722/51 with a final overall average store of 20 t DM/ha produced markedly less shoot mass than the poplars. The average annual growth was only 4.0 t DM/ha; however, the willow caught up noticeably during the last two years of the first rotation and then produced an average biomass of 7 t DM/ha·yr.

Neenan (2) reports annual growth of 11 and 14 t DM per ha for Salix viminalis in the 5th and 7th year of 7-year rotations. According to present data, growth of all clones tested is greatest on plots which are only moderately moist with a well-drained, brown topsoil. On moist to wet sites affected by ground-water, growth is usually retarded.

Fertilization with nitrogen had a significant effect on nutrition, height and shoot mass production only in the 5th growing season 1987 and only in 3 of the 4 species. So far, use of fertilizer has not increased growth of the aspen at all. It therefore seems that release of P, K, Ca and Mg (N) from the former arable soils on our experimental areas were sufficient for high biomass production of the poplars in the initial years.

The generally expressed fear that planting of fast-growing tree species in short rotation would involve unjustifiably high ecological risks has so far not been confirmed in our tests.

A shallow soil cultivation was necessary only in the first year to control the vigorous spread of ground vegetation. For the four subsequent years the soil remained completely undisturbed by mechanical influences on soil structure and organisms. Only when the harvest took place in Jan./ Feb. 1988 a tractor was driven over the ground again. So far it has not been necessary to use pesticides, nor was there any evidence of danger to poplars and willows from rodents.

Our comparative analyses of soil samples for 1983 and 1986 so far show no significant changes in important soil chemical properties (Lebuhn 1989). A tendency towards a slight drop in pH values however was discernible. Base saturation also tended to drop due to lower calcium saturation at the exchange complex. Loss of nutrients through seepage was not significantly affected by the experimental fertilization of poplars and willows. The concentrations of NO_3- + NH_4-N in the seepage water, however, generally dropped from 18 mg to 4 mg/l in the years 1984 to 1987; higher NO_3- + NH_4-N-concentrations were always measured in soils from arable fields than from poplar and willow plots. We therefore assume that the loss of nutrients from the solum was reduced, since the fast-growing trees with well developped root systems were capable of extracting the available nutrients efficiently.

In 1987, a comparison of the ground vegetation on the experimental area, on fields and on unused marginal strips revealed a surprisingly large number of 145 species for the plantation as opposed to 17 for the field. There was a significant negative correlation between tree and ground vegetation biomass, the ground vegetation (at a maximum) achieved above-ground biomass stores of 2 t DM/ha, containing up to 36 kg N/ha. These figures emphasize the importance of the ground flora as an interim storage for nutrients in the initial establishment phase and during regrowth after harvesting (Heilmann 1988).

Changes in the earthworm fauna underline the gradual biological regeneration of the soil. We are following this development with great interest, since, apart from ecological and faunal aspects, the establishment of an effective soil fauna can be expected to have a positive effect on important soil properties.

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APPENDIX

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SITE RELATIONSHIPS FOR SOME WOOD PROPERTIES OF PINE SPECIES IN PLANTATION FORESTS OF SOUTHERN AFRICA

C.J. Schutz, S.I. Christie and B. He[illegible]san*

Sabie Forestry Research Centre, CSIR, Private Bag X520
1260 Sabie, South Africa
*Mondi Forests, P.O. Box 39, Pietermartizburg 3200,
South Africa

FDC: 547: 811.2: 812.31: 815.5: 174.7 Pinus spp.: (68)

SUMMARY

Although genetic variation in wood properties of the three main pine species planted in southern Africa is high, there are important site relationships.

1. *Density*. A study of density in *Pinus patula* on 147 sites in the main forestry region showed that wood formed during the early years was influenced mostly by soil properties, whereas wood formed later in the rotation was influenced more by climate. Density gradient was more closely related to site than was inner density, outer density or mean density.

2. *Spirality*. The same study indicated that spirality decreased as site quality improved.

3. *Stem bumps*. Nodal swellings in *P. patula* increase in size with age, affecting strength properties and veneers. Regression models contained site variables strongly related to stem stability and to exposure. It was concluded that bumps are a reaction by the tree to wind-induced stresses at the zones of greatest weakness, viz. at the nodes.

4. *Heartshake*. Resin-infiltrated heartshakes cause severe losses in the recovery of sawn timber of *P. elliottii*. Research indicates a role of soil moisture in that the problem is more severe on wet sites.

5. *Abnormal wood*. The incidence of this defect in *P. taeda* has resulted in the suspension of planting of this species by many growers. Abnormal wood is similar to compression wood except that it occurs concentrically and has properties which makes the wood unutilizable. The problem appears to be strongly related to site quality and soil moisture conditions.

Keywords: Site, wood properties, southern Africa

INTRODUCTION

A great deal of research has been undertaken world-wide to obtain a better understanding of relationships between site and tree growth. Less attention, however, has been given to wood properties. Recent studies have shown that site cannot be ignored when considering variation in wood properties and the causes of certain defects of timber. Density and spirality, and the incidence of defects such as heart shake, abnormal wood and stem bumps in pine plantations in southern Africa are examined in this regard.

1. Density

Density is generally regarded by wood technologists as the single most important wood property, as it is closely related to timber strength, pulp yield and pulp quality (Cown 1974). Consequently density has been the most widely studied wood parameter with regard to site relationships.

Most studies have concentrated on macro-scale geoclimatic influences. An inverse relationship between density and both latitude and altitude has been reported in many parts of the world (Cown 1974, 1981; Ledig *et al* 1975; Talbert and Jett 1981; Tsoumis and Panagiotidis 1980; Wahlgren and Schuman 1975; Wright *et al* 1987; Zobel *et al* 1960). A possible explanation for the effect of latitude is that the shorter the growing season (in higher latitudes), the less time there is for the production of photosynthate necessary for cell-wall thickening. This decrease in the amount of cell-wall substance results in a decrease in density (Ledig *et al* 1975).

Fewer studies have been done on the more localized effects of site, and the results have often been conflicting (Zobel *et al* 1960). Site quality (soil properties) ranges in its effect on density from negative (Sluder 1972), to positive (Tsoumis and Panagiotidis 1980), to no effect, (Hamilton *et al* 1978). Soil moisture parameters have been found to have some influence on density. Working with clonal material of *P. radiata*, Harris *et al* (1978) found that density was inversely related to moisture stress. There was a similar trend with soil moisture retention capacity in the case of *P. caribaea* (Cown 1981). Other reported relationships were for soil parent material (Hamilton *et al* 1978) and for phosphorus deficiency, which resulted in higher density (Harris *et al* 1978).

A study of site-wood density relationships in *Pinus patula* Schiede and Deppe in Schlect. and Cham. was recently undertaken in the main forestry region of southern Africa (Eastern Transvaal Drakensberg Escarpment) by Schutz (1989).

Wood samples were taken from mature *P. patula* trees on 147 sites selected to cover the widest possible variation in the 100 environmental factors recorded on a 0,1 ha plot at each site. A disc was removed at 3 m height from each of the 10 largest diameter trees felled on each of the plots. Rejection of samples due to defects and other problems resulted in a sample size of 8 trees, and in a few cases 7 trees, per site. The total number of trees sampled was 1146. Extracted wood density was determined according to the method described in Schutz (1989) and the following density parameters derived:

(i) Inner density (year rings 1 to 8)

(ii) Outer density (" " 23 to 30)

(iii) Mean density: $\frac{(\text{inner density} + \text{outer density})}{2}$

(iv) Density gradient: $\frac{(\text{outer density} - \text{inner density})}{\text{inner density}} \times 100$

After determination of plot means, each of the density parameters was used as a dependent variable in regression analysis, with site, stand, and foliar nutrient parameters as independent variables. Relationships were modelled using best-subsets, multiple and ridge regression. The following results were obtained:

(i) The coefficients of determination for the models were generally low due to excessive between-tree variation, which to a large extent overshadowed between-site variation. Between-tree variation for inner density, outer density and mean density amounted to approximately 90 %. While this indicates that the potential for genetic improvement of wood density is high, it creates difficulties in the study of site differences. Between-tree variation for density gradient was slightly less. However, in spite of the relatively small between-site variation, site differences were very highly significant. A sample size of between 20 and 30 trees per plot is recommended in future studies. Use of clonal material would greatly simplify this type of research.

(ii) Density gradient was more closely related to site than was any other parameter. This may have been due to smaller between-tree variation than in the case of the other density parameters. In regression models, site factors explained 43 % of the total variation in density gradient, 38 % in inner density and 22 % in both outer density and mean density. Coefficients of determination would probably have been higher with a larger sample size.

(iii) One of the most important variables in the model to predict inner density was site index, an expression mainly of soil properties. With increasing site index, inner density decreased. On the other hand, the most important variable in the model to predict outer density was altitude, an index of temperature. With increasing altitude, outer density decreased. Wood formed during the first eight years would thus appear to be influenced mostly by soil conditions, whereas wood formed later in the rotation is influenced more by climate (temperature).

(iv) Of all wood density parameters density gradient was the most strongly related to site. The most important variable in the model was site index. Density gradient was more dependent on variation in outer density than in inner density.

(v) Although site index was an important predictor of inner density, this does not necessarily conflict with the findings of Turnbull (1947) that density is not affected by growth rate, for a specific site. The fact that variables which do strongly express rate of growth, viz. D.B.H., present height and stems per hectare, did not appear in any wood density models, either in addition to site index or as alternates, lends some support to Turnbull. Certainly the findings do not contradict those of Turnbull.

(vi) Stand parameters did not appear to play an important role in determining wood density.

2. Spirality

Spirality is an important wood defect causing warp, twist, and loss of strength in sawtimber and veneer (Kromhout 1966). From the literature it is evident that the relationship between wood spirality and environmental factors has received very little attention. In *P. sylvestris* in Norway, spiral grain was found to be the highest in areas of poor growth (Kaasa 1976). In *P. radiata* in Australia and New Zealand, Nicholls and Waring (1977) and Harris *et al* (1978) could find no response to different controlled conditions of moisture and nutrients.

Site-spirality relationships for *P. patula* in southern Africa were studied in conjunction with the density investigation described above.

Spirality determinations were done on the same samples as those for wood density. Samples were prepared and grain angles measured on opposite radii according to the method described by Kromhout (1966). A total of 6960 samples was measured. The following spirality parameters were derived:

(i) Spirality at 8 years
(ii) Spirality at 22 years
(iii) Spirality at 30 years
(iv) Mean spirality (mean of 8, 22 and 30 years spirality).

Results were as follows:

(i) Between-tree variation for spirality was even greater than in the case of density, reaching 99,9 % for 30 year spirality. As a result, although there were significant differences between sites, significance levels were much lower than in case of density parameters, and 30 year spirality was in fact not significant. For the proper study of site effects, very large sample sizes would therefore be required.

(ii) In regression models site factors explained 29 % of the total variation in 8-year spirality, 17 % in 22-year spirality, 15 % in 30-year spirality, and 27 % in mean spirality.

(iii) Spirality decreased with an improvement in general site properties.

(iv) Spirality generally decreased from 8 years to 30 years.

3. Stem bumps

Surface irregularities other than cankers on the stems of forest trees have variously been termed bumps, swellings, ridges, bulges, knobs, and protuberances (Banks 1956; De Villiers 1974; Mergen and Winter 1952; Phillips and Patterson 1965; Tressel 1970). Locally they have also been described as nodal swellings, lumps, corrugations or mae wests. In this paper the term "bumps" is used.

Reports on bumps resulting from compression failure after severe wind storms have been reviewed by Mergen and Winter (1952), who found that bumps developed as reaction to compression failure on the leeward side of the stem, in several conifer species in Europe and the USA. This type of stem bump development has frequently resulted from storm damage in *P. patula* stands in southern Africa.

More common in *P. patula*, however, is a type of bump which is not associated with compression failure, but which occurs as nodal swellings either all around the circumference of the stem or on one side only, and more prominently near the butt than higher up the stem. Wood properties most affected by these stem bumps are modulus of rupture, fibre stress at proportional limit, and maximum crushing strength in compression parallel to the grain (Banks 1956). There are also problems in the sawing of the timber, and the quality of veneer logs is adversely affected. The possible causes of this type of stem bump is unknown, and was the subject of this study.

The survey conducted for the study of wood density and spirality described in 1 and 2 above provided an opportunity also for an investigation into stem bumps and their possible causes. Bumps were assessed on the basal 3 m of each tree on each of the 147, 0,1 ha plots used in the wood density study as follows: (1) Size index: visual assessment on a scale 0 to 5 (the zero index indicating a "clean" stem, the 5 index a stem with the largest size of bumps) (2) Extent in horizontal plane, i.e. whether all round the stem or more strongly developed on one side only. (3) Orientation (if on one side of the stem only). 5311 trees were thus assessed. In addition trees on sites with severe bump development were felled and sawn into boards for an examination of the internal structure of bumps and affected timber. Regression models were constructed for the prediction of bump size index as well as the percentage of trees with severe bumps, from site and stand parameters. The following results were obtained:

(i) Compression breaks in timber from trees with bumps were rare, but severe grain deflection and even grain separation usually occurred.

(ii) With few exceptions bumps started developing after pruning, but not all pruned trees developed bumps. There was no correlation between knot size and bump size. Bumps usually increased in size with age, but caused grain deflection from an early age.

(iii) Only 7 % of the 5311 trees assessed had completely smooth stems. 10 % of all trees in mature stands had severe bumps.

(iv) 23 % of trees with bumps had bumps more strongly developed on one side, mostly on the north to north-west side but to a lesser extent on the south side. These bumps were found exclusively in trees with eccentric growth and always on the side closest to the pith.

(v) Regression models for the prediction of bump severity from site variables accounted for up to 61 % of the total variation, the balance being largely attributable to genetic variation. Key predictors in the models were altitude (quadratic), rainfall, soil colour hue (B horizon), slope position, geology and stand age.

The results above are interpreted as a strong indication that wind is probably the major cause of stem bumps:

(i) Bumps which were more strongly developed on one side of the stem were not randomly oriented but faced in specific compass directions.

(ii) Bumps were least severe at high altitude (range 900 - 2000 m). As trees at high altitude are shorter and have a higher taper, stems should be stronger than at lower altitude.

(iii) Bumps increased in severity with increasing rainfall and yellowness of the subsoil (B horizon hue), i.e. wet soil conditions. As root development is adversely affected by wet soil, stem stability could be reduced.

(iv) Bumps were more severe on ridge tops than on mid and lower slopes, and least severe on foot slopes. In this case the predictor slope position is probably an expression of exposure.

(v) Of seven different categories of geology expressed as dummy variables, only one appeared as a predictor of bump severity, viz. the Selati Formation. Bumps were more severe on this substrate. As the Selati Formation is located along the exposed edge of the Escarpment, this could also indicate a wind effect.

(vi) Bumps increased in size with age. The tendency of *P. patula* to develop wide, heavy crowns with increasing age results in a decrease in stem stability.

(vii) Trees with severe bumps were found to have a higher outer wood density. This could be a reaction to wind stresses.

If these factors can be accepted as being related to susceptibility to wind stresses, then it is likely that bumps are a response to these stresses at the zones of greatest weakness on the bole, viz. at the nodes, and in the lower part of the bole, where these stresses are likely to be strongest. A more apt term for bumps would therefore be "crumples".

4. Heart shake

Heart shake can be defined as a series of internal cracks in the radial and longitudinal planes of standing trees and is the most common and serious defect of South African-grown *Pinus elliottii* Engelm. (Darrow, 1982). Shake results from the separation of the wood fibres, parallel to the grain and is often associated with the production of resin which infiltrates these cracks. At some point along the vertical extension of the bole, the defect almost always touches the pith, hence the common name 'heart shake'. In economic terms, heart shake causes considerable losses in saw timber yields. In 1973, a rebate system was introduced by the Forestry Branch of the Department of Environment Affairs in order to compensate for mill losses (Pretorious and Antwerpen, 1978). At present, a rebate system is still in operation.

Yamamoto and Kozlowski (1987) observed an increase in the production of resin ducts in the xylem of *Pinus halepensis* following the application of etherel. This is consistent with studies showing similar responses in *Pinus radiata* (Barker 1979), and *Cedrus libani* (Fahn *et al.*, 1979). In addition, ethylene production was stimulated by the flooding of soil. This triggered the formation of longitudinal resin ducts in the xylem of *P. halepensis*. In some gymnosperms traumatic resin ducts form in response to injuries caused by various mechanical stresses including wounding (Fahn et al., 1979, Yamamoto and Kozlowski, 1987). Ethylene might be a predominating factor in the hormonal complex that regulates differentiation of traumatic resin ducts (Yamamoto and Kozlowski, 1987)

Shigo (1972) in Darrow (1982) was of the opinion that wounding and infection by micro-organisms alone, cannot be considered causal factors in the development of heart shake, but that genetic tendencies, climatic extremes, weakened wood structure and exposure to microbial agents, strongly influence the possibility of heart shake development. Darrow (1982) attempted to associate the incidence of heart shake with certain tree variables in the hope that physical form or characteristics of a particular tree would be indicative of the presence of heart shake. No significant correlation could be established between the physical form i.e. height, diameter at breast height (1,3 m), crown class and occurrence of heart shake. Similar results were obtained when factors such as age, growth rate and branching characteristics were considered. He concluded that the possibility of genetic differences among families could not be ignored.

Darrow (1982) believed that heart shake has a biological origin and resulted from the wounding of young seedlings due to poor nursery and planting practices. He described three factors which in combination could cause and aggravate resin-infiltrated heart shake, viz.

a) encased nursery soil
b) distorted tap roots
c) small dead resinous roots

There was no indication that tree height is correlated with the incidence of heart shake. This is contrary to Van der Sijde's (1976) findings that dominant and co-dominant trees revealed a higher incidence of heart shake.

In studies carried out by Darrow (1982), none of the planting techniques studied had an effect on the incidence of heart shake. Nursery stock types however, had an influence on the incidence of heart shake. This supports his hypotheses that encased nursery soil, distorted tap roots and small dead resinous roots could cause and aggravate heart shake.

However, a far higher incidence of heart shake occurred on the wetter and poorly drained of the two study sites. If one takes Yamamoto's and Kozlowski's views into consideration, this higher incidence of heart shake might be ascribed to the poor drainage and consequently high ethylene production on this site.

Results indicate that a possible nursery stock type/site interaction might be occurring. Further experiments are needed to determine if etherel-stimulated growth appreciably effects wood quality and increases the incidence of heart shake. In addition the possibility of genetic differences among families requires investigation (Christie 1990).

5. Abnormal wood

Abnormal wood is found in the progeny of certain of the selected clones of *Pinus taeda* L. growing in the summer rainfall region of South Africa (Van der Sijde *et al* 1985, Herman 1988 a, 1988 b). The problem is so serious that planting of *P. taeda* has been suspended by many growers. The abnormal wood consists of full increments of anomalous compression wood type tracheids formed immediately after the first thinning in susceptible trees. The abnormal wood is very difficult to saw and sawn planks warp on drying. Similarly the abnormal wood has to be mixed with normal wood for pulping or yield and quality are severely affected. The abnormal wood formation is related to changes in plant growth regulators in the susceptible clones, controlled by the thinning and pruning regimes. The site the tree is growing on can ameliorate or enchance the formation of the abnormal wood.

The formation of abnormal wood in certain progeny of selected *P. taeda* families is related to the plant growth regulator metabolism and the silvicultural regimes they are grown under. Both of the above are the main factors in causing abnormal wood i.e. the right genes must be present and the silviculture switches them on and off. However the main factor in modulating the extent to which the problem is seen is the site that the trees are planted on.

Pillow and Luxford (1937) reported that *P. taeda* growing in "rich" soil produced full increments or compression wood regardless of inclination, suggesting that vigour was related to the formation of this wood. Similarly the formation of abnormal wood on various sites around southern Africa, although controlled by genetics and silviculture, is modulated by site. Several sites were studied to assess the relationship between abnormal wood and site, examples of which are the following:

Site 1: Tweefontein State Forest. On a deep, well-drained soil derived from dolomite in a foot slope position, 22 % of the trees had abnormal wood, in comparison with 12 % of the trees higher up the slope on shallower, stony soil. The trees were of the same clones within the same compartment.

Site 2: Bergvliet State Forest. On a deep but poorly drained soil derived from granite in a valley floor position, 23 % of the trees had abnormal wood, compared with 13 % on well-drained soil higher up the slope. The trees were of the same clones within the same compartment.

Site 3: Waterhoutboom Plantation. On a wet, granite-derived soil with a very high water table in a valley floor position; 87 % of the trees showed severe abnormal-compression wood formation.

Site 4: Klipkraal Plantation. Genetically identical trees to those on Site 3 had also been planted on shallow, nutrient-poor sands derived from quartzite. Only 7 % of these trees had abnormal wood.

The evidence from the study of these and other sites strongly suggests that abnormal wood formation in susceptible clones is more severe in vigorously growing trees on good sites than in trees of slower growth on poor sites, and that the problem is further aggravated by poor soil drainage and wet site conditions. In *P. taeda* there is evidence to link vigour to auxin concentration which is higher in vigorous trees. Auxin in turn has been found to be directly related to the formation of compression and abnormal woods. On the wetter sites abnormal wood formation appears to be related to ethylene metabolism. This may be related to some of the findings of Fayle (1976) and Timell (1986), relating compression wood formation to ethylene production in wetter soils.

CONCLUSION

Although genetic variation in wood properties of pine species grown in southern Africa is high, the results of recent studies show that site cannot be ignored when considering variation in wood properties and the causes of certain defects. The relationship between soil drainage and stem bumps in *P. patula*, heartshake in *P. elliottii* and abnormal wood in *P. taeda* is particularly noteworthy.

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Strategies and Tactics in the Study of Forest Nutrition and Productivity Relationships

by

G.F. Weetman
Faculty of Forestry
University of British Columbia
Vancouver, B.C., Canada

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SUMMARY

In the absence of good techniques to quantitatively determine the availability of nutrients to trees, researchers must rely on indexes and indirect measures. The measurement of uptake of nutrients and tree and stand response is complex. Careful strategic and tactical planning is needed in examining forest nutrition and productivity relationships. The logistics can be formidable and expensive and require long-term commitment, particularly if empirical fertilizer testing is used. A review is made of the issues, options and current trends, including the use of expert systems. A listing is presented of different techniques for determination of tree and stand growth response and tree and stand nutritional status.

INTRODUCTION

There are many techniques available to study relationships between the growth of trees and stands of trees and their nutrient supplies (see Tables 1 and 2). The researcher is faced with a choice of many analytical techniques and experimental procedures. There is often a tendency to generate foliar, soil nutrient analysis and tree response data that is not very revealing, or to use greenhouse or growth chamber experiments whose outcomes have little relation to forest conditions.

Since closed forest stands recycle their nutrient supply, via litterfall, and also store nutrients in above-ground humus and litter layers, there is not the dependence of trees on mineral soil nutrient supplies as seen in agricultural crops. Agronomic soil analytical techniques for "available" nutrients are often poor indices of supply to forest trees, a problem which is confounded by the mycorrhizal associations on tree roots which mediate nutrient uptake in unknown ways.

It is thus important to distinguish between nutrient demand before crown closure when supply is mainly dependent on soil nutrient availability, and nutrient demand after crown closure when nutrients are recycled. The processes which regulate nutrient flow within a forest system are: (1) uptake by higher plants, (2) translocation and use within the plants, (3) return to the soil and forest floor, (4) mineralization, immobilization, and leaching of the returned nutrients, (5) inputs of nutrients from atmospheric, geologic and biological sources, and (6) losses in streamflow, harvesting and volatilization to the atmosphere. (Jorgensen and Wells 1986).

The problems of relating nutrient supply to growth and yield are complicated by the conventional problems of tree and stand growth and yield measurement, which are demanding in terms of replication, time and complexity of analysis. The complexities of both sets of methodology options, nutrition and growth and yield response, makes for difficult decision making in planning research work.

This paper cannot review all the complexities, but does comment upon some of the useful approaches that are used to study forest nutrition and forest productivity relationships.

STRATEGIES

The strategic problem is that of deciding what is to be studied, i.e. setting the objectives of the study. A review of the large literature on forest nutritional relationships indicates that setting an objective is not easy. Many questions arise: Is a diagnosis needed of a nutritional problem? Is a predictive tool needed to forecast future nutritional problems and situations? Is an explanation needed for variation in tree growth, or distorted growth, lack of growth or unhealthy appearance? Is a quantitative answer needed? Is a qualitative answer needed? Is an index, or indicator needed to characterize the nutritional problem? Is a short-term or a long-term answer needed to the problem? Is it a monitoring problem? Is the problem at the scale and level of the individual seedling of trees, stands of trees, or whole forests of trees? Is scientific understanding of the problem needed or merely a solution? Is it a laboratory, nursery or field problem? What are the ages of the trees and state of stand development? The answers to these questions dictate the strategy to be used. Fundamental to the answers is the question of portability of information and its implementation. Two very important questions arise: (1) can results for the seedlings in greenhouses and laboratory studies be extended into the forest? (2) What is the forest classification or soil or site classification framework that is used to identify units of forest of equivalent fertility? The answers to these two questions do largely dictate the approaches used.

The problem of portability of results from seedling studies in the lab and greenhouse to the forest is particularly important in tree nutrition. As has been pointed out by Miller (1981) the nutritional demands and relationships of forest stands change with time. Data and indexes which are appropriate for nurseries are not appropriate for closed stands of trees. Lab and greenhouse studies are more controlled, but important field variables (e.g. temperature, competition, etc.) are not considered.

The site or soil classification framework has been fundamental in explaining differences between the United States and Canada in the conduct of forest nutrition studies. The United States forests are largely soil mapped, based on the early work of the Soil Conservation Service. Forest nutrition studies have tended to relate mapped soil properties and characteristics to fertility (e.g. traditional soil/site studies relating site index to soil properties or fertilizer trials related to mapped soils. Canadian forests remain largely unmapped, but instead are classified in manuals into forest site units based on edatopic grids of ranked moisture and nutritional regimes, often identified phytosociologically by the occurrence of plant species. Forest nutrition studies tend to be related to the nutritional rating in the grid. Site index is related to the phytosociological classification. Fertilization trials and seedling nutrition studies also relate to the grid, since the grid is used to identify the field condition of the forest. Since many nutritional problems involve closed canopy stands with nutrient recycling, pot trial and greenhouse approaches are not often helpful.

Australia, New Zealand and South Africa, where pine plantations are established on previously unforested mineral soils, like the United States the nutritional problems tend to be related back to the soil's characteristics.

TACTICS AND LOGISTICS

Having chosen a strategy, the question of choice of many techniques arises, together with the problem of conduct of the study. Studies conducted in the forest i.e. *in situ* have the advantage of dealing with the realities of the forest ecosystem, the problems lie in the lack of control of the many site and stand variables, difficulties in sampling and logistical problems and high costs of field studies.

Fundamental to the choice of tactics is the lack of understanding of exactly how trees take up nutrients in field situations. Mineral nutrition studies, notably the work of Ingestad and co-workers, has shown the importance of flow rates rather than concentration in determining nutrient uptake in mineral nutrition. When trees are growing in mineral or organic soils, before crown closure and have no mycorrhizal infections, even without the complication of nutrient recycling, there is still no reliable way to determine quantitatively the real supply of available nutrients to

trees. At best, we still only have indexes: available N, available P, mineralizable N, etc. Use of ^{15}N and ^{32}P techniques still do not yield reliable nutrient availability data.

When the situation is confounded by the supply of nutrients coming form both soil reserves and litterfall recycling, the use of conventional soil nutrient analysis techniques becomes even less satisfactory. This situation has forced attention on measures of tree uptake (phloem and sap analyses, static foliar analysis, foliar vector analyses) and tree response to added nutrients (plant growth analyses, height growth, unit leaf or fasical weight, site index, height intercept). Rating and ranking forest sites for nutrient availability or levels of fertility often use indirect measures. (Phytosociological classification or use of indicator plants, humus form or classification or even site index) as well as direct measures of conventional soil and nutrient availability.

Forest studies must deal simultaneously with a mosaic of ecosystems of different levels of soil fertility, plus stands of different ages. The substitution of space for time in chronosequence studies is common, but there is the requirement that the sampling be done in ecosystems of the same fertility, if the time relationship of nutrient availability is to come out clearly in the data set. Even with this requirement met the validity of substituting space for time is still questionable on the grounds of changes in climate and stand history in the chronosequence.

One way to avoid this issue is to sample stands as case histories, present the best explanation of the nutrition/productivity relationship possible and leave it to the reader to find utility and implementation. However, so much of the literature, particularly in textbooks is really case histories, that it leaves the researcher, practitioner and student wondering what is the application of the finding.

The search for absolute values, of wide applicability, for nutrient uptake (such as static foliar analysis values) is fraught with problems. Even the foliar analyses values have wide variability (see van Breeman review of literature). The world-wid comparisons of laboratory foliar analysis values done by Will and Sandberg (1988) of the New Zealand Forest Research Institute (and presented to the last IUFRO Congress) show how unreliable the analyses can be. There has been recent interest in DRIS indices as a way to obtain more universal indicators. However, calibrations against high yielding stands is difficult when optimally grown stands are rare.

Thus, optimum nutrition trials have been sued to examine the relationship between nutrient availability, supply and response, particularly the upper level of response. This work, pioneered by C.O. Tamm and subsequent workers has shown spectacular yield increases even in stands in boreal climates. These findings have shown unsuspected nutrient constraints on forest productivity. The availability of computer controlled forest irrigation systems, using

Ingestad A and B solutions to provide optimum nutrition, now makes field experimentation easier. Fertilization x Irrigation treatments ("Fertigation") are now used to explore the upper limits to forest productivity. However, the expense and logistics of such experimentation are formidable. Notable examples are the studies at Wageningen in Holland in Douglas-fir and Scots pine and at Canberra, Australia in radiata pine.

This tactical approach recognizes the truth that the best way to study a complex forest nutrition problem is, in the final analysis, to actually add nutrients to the forest and then examine the response, i.e. kick the stand nutritionally. This tactic can use screening trials with foliar vector analysis (for one-year studies) or conventional plot fertilizer trials (for 3- to 20-year studies). Nutrients can be added singly, in factorial combination, in substractive trials or in optimal supply through irrigation solutions.

The design and layout of such fertilization trials is complex. The huge number of forest fertilization trials across the world, and cooperative testing schemes, shows that empirical testing at the stand level is necessary in forest nutrition/productivity studies. Logistically, these large-scale testing programs require considerable commitment and expertise.

Making sense of the data sets for such large-scale testing is also formidable. Besides the problem of following nutrient uptake, there are a host of forest biometric problems associated with the remeasurement of permanent sample plots. Data collection must be disciplined and consistent. Ways must be found by experimental design, layout and choice of measurement variables to overcome stand and site variability, competition-inducted mortality and climatic variation.

From all the empirical testing using fertilizers, plus studies on stands of naturally varying fertility, there is produced a huge mass of information about each tree species. When hundreds of stands are tested and studied over many years it becomes possible to calibrate and understand fertility on different sites. There is current interest in developing expert systems, i.e. computer-based systems, using transparent reasoning and the evidence from many stands and sites to develop more universal diagnostic procedures. Although used in medicine and other fields, their application in forest nutrition is new. The availability of Pro-Log for MacIntosh computers aids in its use. A recent example is the expert system proposed for Sitka spruce (Thompson and Taylor 1990). The advantage of such systems is that a range of site and response information can be "looked up' and logically reviewed. In theory, someone with 30-years of experience in this field could put his knowledge into such a system rather than leave it in scattered and non-integrated publications.

Besides continued interest in improving forest stand growth rates by fertilization, there is rising environmental concern over

the sustainability of forest crops and the impacts of pollution ("acid rain") and global warming. IUFRO was founded almost 100 years ago in Germany when the issue of nutrient export in litter raking and associated decline in fertility was an important research topic. One hundred years later, the central scientific nature of this problem is still with us, but now related to whole tree logging, repeated use of fire and pollution. We still seem to be highly constrained by the lack of good techniques to study nutrient availability. More basic study is badly needed. Lacking really good techniques to measure forest nutrient availability to trees, we must rely heavily on empirical testing. However, the complexity, cost and commitment of such studies does require careful attention to strategies and tactics. Long-term field experimentation is becoming very important in the study of changes in chemical climate on ecosystems (Tamm 1984).

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Table 1: Tree and Stand Growth Response Measurement

Technique	Comment	References
1. Plant growth analysis		
(a) Sub-organismal demographic analyis	Treats the organism as a population of structures, and assesses its demography (births, deaths, prominence and organization of sub-classes of structures). Not much used in forestry.	Lovett, Doust and Eaton (1982)
(b) Yield component analysis	Analysis variation in yield as a product of variation among yield components, each component being a ratio of morphological measures mainly used in agronomic research	Fraser and Eaton (1983) Eaton, Bowen and Joliffe (1986)
(c) Conventional plant growth analysis	These are time-based analytical models of growth and yield which are a function of presence, efficiency, extent, persistence and partitioning. These are very useful in forestry	Hunt (1982) Ledig (1974), Brand, Weetman and Resler, (1987), Brix (1983)
2. Conventional forest biometry		
(a) Height growth	Some species do not respond well in height but mainly in diameter	Hazard and Peterson (1986) Kukkola and Saramaki (1983)
(b) Site index and height intercept	Height intercept is usually well correlated to Site Index.	Oliver (1972)

Technique	Comment	References
(c) D^2H, $\sqrt{n} \times h^2$, basal area and total volume with covariance analysis.	Need for permanent sample plots is demanding in terms of homogenous stand spruce needed for an experiment and number of replicates.	Woolous and Whyte (1988)
(d) Simulated stand yield response in computers. (individual tree (and stand level)	Various competition, mortality response assumptions must be made in stand simulators	Lowell (1988)
3. Use of foliage measures		
(a) Foliar biomass responses	Costly and difficult to measure	Axelsson (1985)
(b) First-season foliar unit weight	Usually well correlated with subsequent volume response; gives quick response estimate.	Weetman, Fournier and Schnorbus (1988)

Table 2.

Determination of Stand or Tree or Seedling Nutritional Status

Technique	Comment	References
1. Site classiification based on natural variation in fertility		
(a) Phytosociolgical techniques	Explaining the scientific basis for good correlations between ground vegetation and forest fertility is difficult. An early but pragmatic approach for boreal forests	Schonau (1988)
(b) Biophysical techniques using plant and soil parent materials	Current trend is to rank nutrient regime on relative scales. Quantification of the scales is difficult and very pragmatic	Zelazney *et al.* (1989) Timmer (1987)
2. Soil classification and analysis based on natural variation		
(a) Humus form classifications	Long history of use, pragmatic, hard to quantify; useful for silvicultural treatment	Klinka *et al.* (1981)
(b) Conventional soil nutrient analysis for 'available nutrients', mineralizable soil N	Chemical extractions do not simulate real availability to trees, at best are indexes of local or species specific use: Used to characterize sites and soils.	American Society of Agronomy (1990), Powers (1984), Khanna (1981)
(c) Total nutrient content of soils	Not usually an approximation of availability	

Technique	Comment	References
(d) Leachate analyses	Difficult to collect; large variability, useful in nutrient budgeting.	
(e) ^{15}N, ^{32}P and other isotope techniques	Usually costly to apply and difficult to interpret, but can be reliably quantitative.	American Society of Agronomy (1990) Harrison, Ineson and Heal (1989)
3. Mineral Nutrition studies	Seedling values do not always relate well to trees in forest, nor do hydroponic solutions allow for mycorrhizal infections.	Ingestad and Lund (1986)
(a) Static foliar nutrient concentrations	Seedling values not often valid for older trees. Uptake may be flow dependent. Confers tend to maintain high foliar N concentrations in current year tissue. Most widely used way to determine tree nutrient status.	van den Burg (1985)
(b) Foliar vector analyses	Use of first season analyses allows for determination of stand nutritional status and prediction of subsequent response.	Binkley (1986), Weetman and Fournier (1982)
(c) Litterfall, phloem and sap analyses.	Tried, but little used. Do need local calibration to develop standards.	

Technique	Comment	References
4. Empirical testing of nutritional response by adding nutrients to trees or stand		
(a) Conventional fertilizer trials	Response to added nutrient is proof of deficiency. Nutrient interactions and need for balanced supplies complicates testing and interpretation. The most widely used approach.	Bowen and Nambiar (1986)
(b) Optimum nutrition trials	Balanced additions required over a number of years to achieve steady state. Best way to explore upper levels of response.	Tamm (1985)

IMPACTS OF CLIMATE CHANGE ON THE NEW ZEALAND FORESTRY INDUSTRY

Patrick H.B. Aldwell

Scientist
Forest Research Institute, Ministry of Forestry,
Private Bag 3020, Rotorua, New Zealand

FDC: 111.83: 904: (931)

INTRODUCTION

This document reports on the views of forest sector personnel on likely impacts of climate change on the New Zealand forest industry. Effects on industry growth, employment and composition are outlined in the context of possible climate related impacts on the forest resource during the period 1990 and 2050.

The discussion is based on written responses from 14 individuals from forest industry companies and associations and from Ministry of Forestry personnel located through out New Zealand (Appendix 1). Other advice was obtained in discussions with recognised specialists. Respondents' reports were written in response to questions and background material on two climate change scenarios provided to them by the Ministry for the Environment†. These sources of information have been augmented by published material where possible.

The two climate change scenarios comprise a most likely option (Scenario 1) and an upper-limit option (Scenario 2) for the period 2030-2050. Under Scenario 1 temperatures are expected to be 1.5°C warmer than at present, westerly winds will be lighter, sea level is expected to rise by 20-40 cm and precipitation would increase by up to 13% except in eastern coastal regions. Some eastern areas can expect more intense rainstorms.

Under Scenario 2 temperatures are expected to be 3°C warmer, heavy rain storms and tropical cyclones will be more frequent, sea level is expected to rise by 30-60 cm higher than at present and most of the country will experience fewer droughts (Salinger and Hicks 1989).

The forest industry is defined to include all operations involved in the growing, harvesting, transportation and processing of New Zealand plantation forestry products. Indigenous forestry operations are excluded.

A key factor in this project has been the lack of necessary information for quantifying historical and future responses to many aspects of climate change. Thus most of the discussion is qualitative or descriptive in nature and is subject to the assumptions listed below.

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† The rationale and scope for this paper were driven by the New Zealand Climate Change Programme under the auspices of the Ministry for the Environment.

ASSUMPTIONS

This section highlights three assumptions each of which has an important bearing on how the findings in this report should be interpreted.

Assumption 1: That respondents do not have adequate information/knowledge to make confident statements about the impacts of climate change. Thus most statements were provided from a position of considerable uncertainty.

Assumption 2: That the climate change scenarios are an acceptable estimate of future climatic conditions.

Assumption 3: That climate change under scenario one conditions will result in a 20% increase in forest productivity and that, once harvested, forests will be replanted.

STATE OF THE INDUSTRY

The industry can best be described as being "in a state of flux". Two key factors are responsible for this. They are:

(a) the age class distribution of the forests which reflects the planting boom of the 1960s and 1970s, and the fact that this "new crop" forest, whose outputs are about to increase substantially, is untested in the market.

(b) the sale of Crown forest cutting rights on 550,000 hectares. This comprises almost half (45%) of the New Zealand plantation forest estate.

Jointly these two factors generate almost as much uncertainty about the future structure, production, and profitability of the New Zealand forest industry as does climate change. At this time we do not know who will own the forests, nor do we know whether, once harvested, the forests will be replanted.

Currently (March 1988) there are 1.214 million hectares of exotic (plantation) forest of which 90% is in *Pinus radiata*. Present annual wood harvest is some 11 million cubic metres. The domestic market absorbs about 42% of this output, down from 62% as recently as 1986.

By 2020 total harvest is expected to be 26 million cubic metres, provided that all the area planted is harvested at age 30. Depending on technological advances such as genetic gain, and on replanting or new planting, it is probable that production will approximate 25 million to 30 million cubic metres per annum by the year 2030. Thus, ignoring potential effects of climate change, forest output is expected to almost treble in the period leading up to the scenario start date (2030). Assuming domestic consumption is about 6 million m^3, about 75-85% of the total wood supply will have to be sold on the world market. Therefore it is critical in any evaluation of impacts of climate change on the New Zealand forest sector that the impacts of climate change on competitor wood producers are evaluated.

Wood Processing

The wood processing industry is concentrated in the northern half of the North Island. As at the end of 1986 there were 400 sawmills, 6 plywood and veneer mills, 3 particle board mills, 8 pulp and/or paper mills and 4 fibreboard mills. Since 1986 there has been some rationalisation of the industry, especially in sawmilling which has 132 fewer sawmills (mainly very small mills) and about 1500 fewer jobs (Ministry of Forestry Statistician pers comm.).

Log exports are an important part of the industry. In the year to June 1989 log exports totalled 1,544,953 cubic metres, about 15% of the annual forest cut. Whether this part of the forest sector increases its share of forest output in future is uncertain, but the issue has considerable implications for the future structure of the New Zealand forest industry.

CLIMATE CHANGE IMPACTS

Scenario 1

Under this scenario temperature is expected to increase by 1.5°C by 2050, westerly winds will be lighter, and eastern areas more drought prone.

Forest production

Estimates of the effects of climate change on *Pinus radiata* productivity have been conducted by Hollinger (1989), Barlow (1989), and by Conroy et al. (1986). Hollinger's work relates to New Zealand and the other two researchers' work relates to Australia. These estimates suggest, under the above climate change assumptions, that CO_2 fertilisation in conjunction with warmer temperatures will result in increased wood yield of 20% (New Zealand) to 30% (Australia). Other scientists suggest that gains of this order are too high (K. Horgan and Menzies pers comm.).

Hollinger (1989) warns that the techniques used to project forest yield rely on "significant unknowns". One of these is "the extent to which the response of seedlings can be extrapolated to adult trees, given that seedlings are known to differ from mature trees in important ways".

At present *Pinus radiata* forests are growing at an annual rate of 20 cubic metres per hectare (merchantable stem volume). On some sites average growth rates are as high as 43 cubic metres per hectare (Shula1989). Shula notes, in an extensive analysis of permanent sample plot (PSP) data sets, that growing conditions "... for upper limit stands were typified as:

- North Island latitudes (mean of 38.6 degrees south),
- 360 m altitude,
- northerly aspects on uniform slopes (about 15°),
- sandy loam or volcanic soils", and
- no pruning or thinning and with high stocking (1,200 stems per hectare).

Shula did not have climatic data but on consultation with Hunter (a FRI soils scientist) suggested optimum conditions of 12°C and 1500+ mm rainfall.

These data provide an indication of optimum growing conditions. However it should be noted that these forests have been extensively modified to meet production objectives aimed primarily at producing long length knot free sawn timbers in approximately 30 years. This objective requires that stands are thinned and pruned to certain specifications. Thus, irrespective of climate and other ecological factors, different management practices will alter yields (Shula1989). Other factors to take into account when evaluating estimates of future yields under the climate scenarios include:

- The role of genetic improvement which, is likely to increase productivity by 15% to 20%, irrespective of climate change influences (Grace forthcoming).

- The methods used to predict future yields (Hollinger 1989; Pittock 1987).

Clearly considerable caution is needed in interpreting and applying forest yield projections.

Table 1 presents an estimate of changes in wood flow under two growth rate assumptions (13)† . This analysis assumes that climate change will occur at an even rate, that it will increase forest growth rates by 20% and that all harvested areas are replanted. Based on these assumptions " A 15.3% increase in woodflow ... is predicted... over this period (1990 to 2050)", however "... this increase in woodflows is extremely gradual and the percentage change in woodflows is small until, say 2030" (13). In absolute terms this analysis results in an extra 3.7 million cubic metres of wood. These estimates are net of genetic gains and changing forest management techniques.

TABLE 1: Predicted woodflows

Lustrum	Annual recoverable clearfell volume (000 m^3)		% difference
	Base scenario*	20% increase*	
1986/90	8,820	8,820	0
1991/95	9,560	9,590	0.3
1996/00	12,570	12,690	1.0
2001/05	19,000	19,360	1.9
2006/10	22,480	23,160	3.0
2011/15	23,620	24,600	4.1
2016/20	24,240	25,500	5.2
2021/25	24,250	25,850	6.6
2026/30	24,250	26,000	7.2
2031/35	24,250	26,550	9.5
2036/40	24,250	27,200	12.2
2041/45	24,250	27,600	13.8
2046/50	24,250	27,950	15.3

Source: (13).

* Base scenario: Woodflows from New Zealand's exotic production forest without any climate change. This is based on the New Zealand Forest Service's reference scenario developed by Burrows, Levack and Novis (1986) which involves 100% replanting and no more afforestation.

* 20% Increase scenario: A 20% growth rate increase for radiata pine in New Zealand exotic production forests by 2050 as a result of climatic changes is assumed. It is also assumed that the increase will be at a constant rate over this period. The same cutting and replanting strategy as the base scenario is used, and no more afforestation is also assumed.

In these woodflow predictions it is assumed that growth rates alone will change. All other factors are held constant.

The woodflow predictions are for wood from clearfelling only. Production thinning supplies are additional, but not included because of the uncertainties associated with this operation.

The above discussion relates principally to *Pinus radiata*. For Douglas fir (*Pseutodsuga menziesti*), which prefers cooler sites and which occupies 65,000 hectares, half of which is in the northern half of the North Island, the situation is likely to be different (7). "A temperature increase could cause a decrease in area planted in Douglas fir, a species that has specialised end uses and a strong market in Australia" (11). Because rotation length for Douglas fir is commonly 45 to 50 years, there is less time for decisions concerning the management of this species in warmer climates.

In the following sections we examine some factors that could affect the estimates shown in Table 1.

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† Reference numbers apply to authors who provided a written report to the Ministry for the Environment (MfE) in response to a MfE survey (see Appendix 1).

Disease, pests and weeds

Most respondents believed that disease, pest and weed incidence would increase under climate change. The introduction of new pests, which is already a problem, will become even more so with climate warming (11). As noted by Hollinger (1989) the fungus *Diplodia pini* is likely to be more prevalent especially in northern areas and in areas experiencing more wind damage. *Diplodia pini* causes malformation of the tree and thus reduces the value gained from pruning. At present there is no known treatment for this disease. A substantial increase in its presence could contribute to the juvenile wood effect on wood quality, thus increasing the probability that the industry will change from a solid wood products base to a fibre products base (10).

A second disease in New Zealand forests is *Dothistroma pini*. At present *Dothistroma pini* is relatively insignificant in Northland compared to the Central North Island. This is mainly because coastal forests are not prone to *Dothistroma pini* (1).

Insect pests are expected to become more prevalent in drier warmer regions. In wetter warmer regions insects themselves will be more prone to fungal diseases (Bain, pers. comm). Increase in insect populations may result in retarded tree growth rates or may result in increased tree mortality. Although some impacts may be gradual, insect population dynamics are often characterised by a boom when certain climatic conditions occur. Thus problems may not become apparent for a long period of time and then suddenly have a large impact (13).

Several weed species find the *Pinus radiata* association ideal. Gorse and pampas grass are a particular problem and while they can be controlled, control is costly. These weeds make access to forest stands more difficult and this adds to the cost of forest operations (Hollinger 1989). If weed species become more prevalent as climate warms, profitability will be eroded. In the more sub tropical areas consideration might be given to establishing tree species or certain genetic strains of *Pinus radiata* characterised by early height growth in order to minimise the effect of weed competition.

Snow and wind

Snow damage is a minor concern to the forest industry, except in parts of Otago and Nelson, and would become even less important with climate warming.

Decrease in westerly winds is unlikely to change the wind damage pattern. However strong winds, especially in the form of gales and storms, are a problem (Somerville 1989). For example 22,000 hectares of forest were damaged by storm events in the 1980s. Since 1945, 19,000 hectares in Canterbury have been wind damaged. Damage means total destruction of a stand, either by toppling or stem breakage resulting in substantial economic losses. "In most instances toppled trees survive but recovery from a leaning position is usually incomplete resulting in residual stem deformation" (Mason 1985). Extreme wind events in merchantable forest can result in a 25% increase in logging costs, 20% loss in volume due to breakage, losses through degradation and deterioration of damaged logs, increased clean up costs and higher accident rates due to difficult logging conditions (Manley and Wakelin 1989).

Regions most affected by wind will continue to be those in the northern half of the North Island and Canterbury.

Drought/rainfall

Pinus radiata is well adapted to drought. It responds by closing its stomata and ceasing growth (10). Thus in regions experiencing more severe drought conditions, *Pinus radiata* may become a less preferred species. Drought is unlikely to be sufficient to reduce the area of forest grown (except in Canterbury), but may affect yields, especially in Gisborne, Wellington, Marlborough and Otago. Insufficient rainfall in the first months after planting may result in seedling loss.

More frequent periods of high intensity rainfall will result in higher road maintenance costs and possibly higher construction costs, especially in steep country. About 40% of existing forest area is on steeper (hauler) sites (Burrows *et al.*, 1987).

Fire

Rather than becoming a problem in new areas, fire will become more of a problem in already dry eastern districts. It is possible that fires could become larger, more catastrophic and therefore more expensive. Currently fires account for less that half of 1% of forest area, averaging about 300 hectares per annum (Cooper 1980).

Terrain rather than climate may be a more important factor in forest fires. Rough, steep terrain favours rapidly moving fires fanned by topographically induced winds. Such fires move rapidly uphill and are difficult to access.

Some forest management practices may have to be changed to reduce the volume of slash in pruned and thinned stands.

Frost

Frost, especially the risk of out of season frosts, constrains site selection and damages new season's growth. Reduction in frost area and in the risk of out of season frosts will increase the range of exotic species and may lead to more eucalyptus plantings. However some eucalypts that prefer cooler areas (e.g., *E. regnans* which is an important eucalypt crop in the central North Island with 7,000 ha planted) may no longer be able to be grown on North Island sites (12).

Wood density

An important element of wood quality is wood density. With increasing wood density there is more fibre content per unit volume, and there is greater strength and stiffness (Haygreen and Bowyer 1982; Wilkes 1988). Wood density increases with temperature and thus within New Zealand it increases from south to north (Cown and McConchie 1983). As Hollinger (1989) notes, under climate change wood density is expected to increase in all regions. If this is the case solid wood products will exhibit greater strength and fibre yield will increase. There is likely to be a minor effect on the quantity of wood fibre available for pulping in Northland. However in the Central North Island fibre increase could increase pulp and paper output by as much as 20% (11).

Rising sea level

Estimates of the effects of rising sea levels are sketchy. Possible impacts include:

- Increased coastal erosion, especially in sand dune forests. This could remove the protective belt of trees exposing the inland trees to salt damage and windthrow (10). Key areas are western Northland and coastal Manawatu.
- Saline water table could rise in the more low lying areas.
- Increased depth in ports.

Industry size and organisation

Between 1990 and 2020 forest output is expected to increase from about 10 million cubic metres a year to about 25 million cubic metres. This increase is expected to happen irrespective of climate change. Thus it is likely that within New Zealand, climate-induced impacts on industry size and organisation, because of their relatively small scale in this time period, will proceed largely unnoticed.

A key factor in determining industry size will be not what is happening in New Zealand but what is happening in those countries competing in global wood products markets. Important countries include those in the high latitude northern hemisphere,

where there is a very large forest resource and where climate change is expected to have a greater impact than in the more temperate areas (Pastor and Post 1988; Shands and Hoffman 1987).

Thus, at least for the period 1990 to 2020, it is likely that market forces rather than climate change will have a more direct bearing on the size and composition of the New Zealand forest industry. However, this opinion must be tempered by the possibility of catastrophic events such as those induced by disease, insect pests and cyclones.

Employment

As noted above, during the next 30 years, the New Zealand forestry industry will be experiencing extensive change accompanied by an expected minor increase in employment. Climate change is not expected to alter this situation during this period (5, 9). Currently there are 148,000 unemployed in New Zealand. The forest industry employs 20,000 (February 1989) down from 25,500 in February 1987.

Market forces and technological change will play a key role in determining the pattern of forest industry employment growth. Although climate change may influence forest growth rates, it is unlikely to determine how, where and when forest outputs will be processed and sold. This decision, and consequently processing-related employment, is a function of the market and how it is perceived by investors.

If climate change increases forest yield by 3.7 million cubic metres by 2050, then forest industry employment could increase by about 2,400 jobs (see Appendix 2). This estimate is heavily dependent on the degree of capacity utilization in existing mills at the time. Because the estimated employment increase is a function of climate-induced changes in wood volume per hectare, no employment gains are expected in forest management operations. However increased volumes may increase logging employment because more crews will be needed to fell the larger wood volumes. This means that most additional jobs will probably be in or near towns where mills and logging contractors are based rather than in rural localities.

Scenario 2

Under this scenario temperature is expected to increase by 3.0°C by 2050, there will be more storm events and more wind from the north. The main difference between scenarios one and two is considered to be an increase in the frequency of tropical storms in the northern half of the North Island (5, 6, 11). More frequent storms are likely to:

- Increase logging costs because of increased damage to logging roads.
- Increase erosion risk in summer months on bare or exposed soils, particularly pumice soils.
- Increase weed and pest problems in areas where forest cover has been depleted or severely damaged.
- Increase the incidence of *Diplodia pini* as a result of wind damage or warmer and more moist conditions.

Under scenario two the impacts would "be similar but strengthened..." with the exception that warmer and wetter conditions would increase the need to consider species other than *Pinus radiata* for Northland (10).

The following submission gives an indication of likely constraints to growth in the Northland region where average temperature would be about 19°C under scenario two conditions. "In Australia radiata pine grows well in 14°C average temperature in New South Wales. However at about the latitude of Coff's Harbour at sea level radiata pine does not grow so vigorously. It appears to suffer badly from *Diplodia pini*. Coff's Harbour has an average annual temperature currently of 18°C and a summer rainfall climate. Radiata pine

is planted in Southern Queensland at high altitude and grows reasonably well at medium altitude. However at sea level in 20°C radiata pine can barely survive. In Fiji at high altitude but in a 20°C climate, radiata pine was a stunted shrub after many years growth. Thus beyond a certain point "tropicalisation" of the climate (including increased summer rain and increased fungal attack) is almost certainly bad for radiata pine." (10). In effect scenario two is likely to worsen the negative effects of climate change characterised in scenario one and this would reduce the benefits derived from higher yields.

TIMING OF IMPACTS

Increase in yield induced by climate change is likely to be gradual and will probably be less significant than increase in output resulting from the planting programmes of the 1960s, 1970s and 1980s (5, 6, 9, 10, 11). From about 2050 climate induced yield growth may achieve a 20% gain over other sources of yield increase (e.g., genetic improvement, improved management, and improved measurement techniques). However it must be recognised that 2050 is two rotations away and thus there is sufficient time to change our forestry options. These could range from clearfelling the current resource with no replanting, or with replanting in only selected areas, through to continuous replanting and even expansion of the exotic forest estate. Market forces and ownership of the State resource will play an important role in determining the character of the 2050 forest estate.

Thus impacts on growth rates and range of *Pinus radiata* are likely to be gradual. This means that the wood processing industry has adequate time to assess the impacts of climate change in the context of the commercial environment. We do not have the positive information needed for industry to make investment decisions in response to climate change effects. At present industry is more concerned about the state of world markets over the next five to ten years and therefore there is more interest in how climate change will affect our competitors and wood supply in world markets. Monitoring and analysis of plant response to climate change will play an important role in evaluating future difficulties and hazards. Provided sufficient attention is given to monitoring climate change interactions in New Zealand and in countries competing with New Zealand in wood products markets, "Most changes are likely to be assimilated relatively easily" (6).

RESEARCH NEEDS

As noted earlier in this report, one of the major difficulties in assessing future impacts associated with climate change is the lack of adequate fundamental long term data and analysis. Improved impact analysis requires work in several key areas. In terms of the commercial forestry sector these include:

- The establishment of sites for long term monitoring and analysis of responses of tree species to climate change.
- Analysis of physiological responses of tree species and their associations to climate change variables.
- Examination of the effects of climate change on nutrient uptake by trees.
- Monitoring and analysis of forest pests and diseases.
- Enhancement of genetics research to target climate variables in strategically important tree species and contingency species.
- Development and enhancement of regional climate/forest response models for New Zealand.
- Monitoring, modelling and analysis of the influence of climate change on New Zealand's competitors in world markets.

SUMMARY AND CONCLUSIONS

Uncertainties currently associated with climate change, the lack of adequate data and the wide variety of possible combinations of market and physiological interactions, make it virtually impossible to provide reliable comment on the implications for the forestry sector. The reader is reminded that this report is based on assumptions listed above (Section 2). Major changes already underway in the New Zealand forest industry will tend to mask effects of climate change over the next 30 years. Key elements of change include a substantial increase in the volume of wood available on the basis of plantings in the 1960s, 1870s and 1980s and the necessity to sell this increased output on the world market. Toward 2050 many of these developments will have become stabilised and climate change impacts will probably become more apparent. To address fundamental unknowns and issues arising from climate change it will be necessary to have a sound long term research programme in place.

Conclusions drawn from the present analysis are:

- In the next 30 to 50 years the most significant feature of climate change for the forest industry will be its influence on our competitors. Increased supply from high latitude northern hemisphere forests into world markets could substantially alter the competitiveness of New Zealand's export dependent forest industry.
- Productivity is likely to increase on most sites with total volume increasing by as much as 3.7 million cubic metres by 2050.
- Increased productivity in conjunction with increased disease, fire and wind risk may encourage shorter rotations.
- Shorter rotations which result in a higher proportion of juvenile wood and/or which have been affected by *Diplodia pini* will probably drive industry away from solid wood products to fibre based products.
- If suitable research is initiated early enough to monitor and gain better understanding climate change processes, the two rotation periods between now and 2050 will allow sufficient time for industry to manage its way through likely climate change outcomes.
- Weeds, pests, and disease are likely to become more of a problem.
- Climate induced changes in the regional distribution of *Pinus radiata* forests are unlikely under scenario one. Under scenario two *Pinus radiata* may no longer be a preferred commercial species in Northland.
- Warmer temperatures may result in a shift in commercial range for Douglas fir and some of the ash group of eucalypts.
- Employment opportunities would be positively affected by climate change especially if forest productivity gains are as high as estimated.

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APPENDIX 1

RESPONDENTS TO THE MINISTRY FOR THE ENVIRONMENT SURVEY

Reference number	Name	Organisation
1	A. Albert	New Zealand Forest Products Limited (Manager, Northland)
2	I. Brown	Hawke's Bay Regional Council (Scientist)
3	M. Collins	Forest Research Institute (Scientist, Timber Engineering)
4	P. Cossens	Forest Research Institute (Scientist, Harvest Planning)
5	O. Cox	Forest Research Institute (Scientist, Wood Processing Economics)
6	D. Evans	Forest Owners' Association (Executive Research Officer)
7	D. Guild	NZ Timberlands Ltd (South) (Manager)
8	M. Hetherington	Dunedin City Council (General Manager, Forestry)
9	G. Horgan	Forest Research Institute (Scientist, Trade, Marketing and Economics)
10	I. Hunter	Forest Research Institute (Research Field Leader, Soils and Site Productivity)
11	D. McLean	New Zealand Forest Products Limited (Manager, Resources)
12	I. Nicholas	Forest Research Institute (Research Field Leader, Special Purpose Species)
13	J. Turland	Ministry of Forestry (Advisory Officer, Policy Division)
14	M. Uprichard	Pulp and Paper Research Organisation (Scientist)

APPENDIX 2

ESTIMATION OF FORESTRY INDUSTRY EMPLOYMENT RESULTING FROM CLIMATE CHANGE

(Assumes 3.7 million m^3 yield increase by 2050)

1 Operation	2 Additional wood volume for operation (million m^3)	3 Man hours per m^3 for operation	4 Man hours per year	5 Employment (man years) $= \frac{2 \times 3}{4}$
Transport to mill[1]	3.15	0.1	1880	118
Wood sawn[4]	1.57	1.0	1880	836
Composite/pulp[5]	1.73	0.5	1880	461
Export logs[2]	0.47	0.2	1880	50
Transport from mills[3]	1.57	0.1	1880	84
Logging[6]	3.7	0.4	1880	787
Total				2436

Assumptions

1 85% of harvested volume is sold to a processing plant.
2 15% of harvest volume is sold as export logs.
3 All locally processed product is transported to final demand.
4 50% of harvested volume is sawn.
5 35% of harvested volume is made into composite wood products; 40% sawmill input goes to composite/pulp mill as residues.
6 Total volume is harvested. New Zealand-wide average harvesting rate is assumed to be 4,500 m^3 per man year.

ENRICHMENT PLANTING IN THE CAMEROON MOIST DECIDOUS FOREST: MICROCLIMATIC AND PHYSIOLOGICAL EFFECTS

D. Eamus*, G.J. Lawson, R.R.B. Leakey & P.A. Mason

Institute of Terrestrial Ecology,
Bush Estate, Edinburgh EH26 OQB, UK

*current address:
Northern Territory University
PO Box 40246, NT, Australia

FDC: 111.84: 161: 181.65: 181.2/.3: 176.1 Terminalia ivorensis

SUMMARY

Measurements of microclimate and tree physiology have been made in order to explain initial differences in growth of Terminalia ivorensis seedlings underplanted in a secondary rainforest after 3 types of site preparation. Growth has been greatest in a mechanical clearing treatment ('Mechanical Recru'), and least in a manual treatment ('Manual Recru'). In the third treatment, complete clearance of the forest and herb layers, the planted trees initially suffered high mortality, but subsequently grew rapidly. These trees also displayed highest light saturated rates of assimilation rates, stomatal conductance and incidence of leaf abscission. Differences between the treatments are apparent in gas-exchange rates, stomatal behaviour, PAR, red:far-red ratio, air-temperature, humidity and degree of canopy closure.

The Mechanical Recru treatment appears to offer a good compromise between the major costs and environmental disturbance involved in Complete Clearance, and the poor growth produced by the shady conditions of the Manual Recru.

INTRODUCTION

There is an sizeable literature describing various physiological, physical and micro-meteorological parameters associated with natural forests in the tropics. Important factors relating to seedling growth include the water relations of canopy and sub-canopy species, the quantity and quality of light reaching the forest-floor, photosynthesis and photosynthetic adaptations of shade and 'open' adapted plants (Medina et al. 1984; Schulze and Zwoffer, 1987; Baker and Long 1986). However, there appears to have been less study of these parameters and processes in forest plantations in the tropics.

The principal planting technique now used in the Cameroon ('Recru') is based on the work of Catinot (1965), and involves clearance of the shrub layer to knee-height using machettes, felling of most middle-canopy trees by chain-saw, and progressive removal of overstorey shade by poisoning. Latterly bulldozers have appeared to provide a cheaper means of clearing the lower and middle layers. The main species used in these plantings is Terminalia ivorensis (Framiré), which is normally planted at 5x5m spacing. Almost all of the standards remaining after the initial site preparation are eventually poisoned, thus the system really constitutes gradual conversion rather than enrichment-planting. Even for these single-species plantations, there appears to be little knowledge of the degree of canopy opening required for successful survival and growth of planted trees. Too rapid a removal of overhead shade encourages the growth of weeds, particularly Siam weed (Eupatorium odoratum), which are costly to control and easy to neglect. Too much shade will inevitably check the growth of young trees, especially with a pioneer species like T. ivorensis.

This paper describes a preliminary study to monitor several meteorological plant physiological parameters in an attempt to understand the processes behind successful establishment and growth of this commercially important West African hardwood.

METHODS

Site Description

The Mbalmayo Forest Reserve is situated at 11°30' N and 3°27' E, at the boundary between the Moist Semi-Deciduous Forest Zone and the Biafran Forest Zone (Letouzey 1965). It is under active exploitation, and most areas have been selectively logged 2 or 3 times. Areas within the reserve were the subject of early silvicultural trials by the French CTFT (Guiscafre 1956), and Recru or line planting has been regularly carried out in recent years, usually with Terminalia ivorensis (Foahom 1982).

The Reserve is at an altitude of approximately 650m with gently undulating relief. Annual rainfall averages 1600 mm, distributed between two rainy seasons (March-June and September-November), with an average daily temperature of 23°C and average relative humidity (RH) of 78% (Foahom 1982). Broadly the soils are classed as a leached yellow-ferralitic type (ultisols and oxisols) and are described in more detail by Tchienkoua (1987).

With the collaboration of the National Office for Forest Regeneration (ONAREF) a site was identified in January 87, 18km south of the town of Mbalamayo, and four one hectare experimental plots were demarcated. These were prepared in May 87 in the following manner.

a. **Complete Clearance:** where the largest trees were felled by chainsaw, and smaller trees and ground vegetation were removed by D8-bulldozer.

b. **Mechanical Recru:** where a bulldozer with a forked blade was used to remove most of the undergrowth and around 50% of the crown cover. The blade was held slightly above the surface to minimize soil damage.

c. **Manual Recru:** where ground vegetation and small trees were removed by machette, smaller trees were cut by chainsaw and larger ones marked for poisoning in subsequent years.

d. **Undisturbed Control:** which received no treatment other than the cutting of narrow access lines for mensuration.

During July and August 1987 planting holes were prepared at 5 x 5 meter spacing, and container-grown, 40 cm high, T. ivorensis seedlings were planted in mid-September. Planting lines in each plot were cleaned 4 times in 1988 and once in 1989.

The 4 treatments, together with a more intensive Mechanical Recru (ie greater canopy removal were replicated in 1988 at a nearby site. However, few meteorological or physiological observations have yet been made on this site, and this paper concentrates on the plots planted in 1987. More information on both sites is reported elsewhere (Lawson et al 1990).

Measurement of Residual Trees

The dbh and species of all trees with a girth greater than 20cm was recorded in March 1988. together with their co-ordinate positions. For logistical reasons it was not feasible to conduct a pre-thinning inventory, but it has been possible to assess the clearing intensity by comparison with 6 ha of undisturbed forest which were surveyed at the same time (in preparation for the p88 planting). A repeat inventory was made in July 1989.

Measurement of Canopy Closure

Canopy closure was assessed photographically using a Minolta fisheye lens (7.5mm) in Feburary (1989) and a Canon (7.5mm) lens in July 1989. The first date was at the end of the rainy season, after the maximum period of leaf-fall, and the second date was well into the rainy season, but after poisoning of some of the dominant trees had taken place to lighten the canopy. The technique involved pointing the lens vertically into the canopy from a levelled tripod, and orientating the camera carefully towards north to allow the solar track to be subsequently superimposed on the image. Between 12 and 32 sample points on a regular grid were used per treatment plot. An image analyser has been employed on the first set of photographs

to calculate the proportion of the sky-hemisphere which is obscured by leaves. More detailed analysis is underway to estimate the total receipt of diffuse and direct solar radiation on the forest floor.

Temperature, RH and PAR

Preliminary measurements were made of photosynthetically active radiation (PAR), red (660 nm) and far red (730 nm) radiation reaching the forest floor. Transects across each plot were made during a single cloudless day in July 1988 (Skye Instruments Ltd. quantum sensors), and soil and air temperature were measured at the same time.

Subsequently, 3-day runs of PAR were obtained from each site, 2 replicate sensors were placed at a height of 1.5m, 40m into each plot, and a third sensor was placed in an adjacent area of uncut forest as a control. A ventilated psychrometer (Delta-T Instruments) was placed at a height of 1m adjacent to the quantum sensor in the uncut forest, and another adjacent to the one of the sensors in the experimental plot. Readings were taken every 10 seconds, and 10 minute averages recorded on a Campbell 21X data logger.

Growth and Mortality of Transplanted Trees

Measurements of the survival of transplanted T. ivorensis were made after 1 month. Height and girth growth of a sample of 100 central trees were recorded monthly from 8 months to 20 months after planting.

Assimilation rate and Stomatal Conductance

Gas exchange across leaf surface was measured with a portable infra-red gas analysis system (ADC Ltd., LCA-2). One healthy leaf was selected from the outer 1/3rd of the lowest branch on the sunny side of 12 replicate trees per treatment. Measurements were repeated hourly on the same leaves throughout the day.

Assimilation rate, stomatal conductance, transpiration rate and CO_2 within the leaf were calculated according to the equations of von Caemmerer and Farquhar (1981, 1984). Assimilation responses to light flux density were modelled using the method of Jarvis et al. (1985).

Stomatal Conductance and Leaf Water Content

One branch from 6 replicate trees from one of the 3 3xperimental plots was excised at 1700 hours, recut under water, and transported to the laboratory and stored overnight to rehydrate to full turgor. Leaves were then removed from each branch and their fresh-weight measured. Leaf

diffusive resistances (using a Delta-T leaf diffusion porometer) and fresh weights were measured repeatedly until the leaf had lost ca 35% fresh weight (Eamus 1987). The procedure was repeated on 3 successive days using a different plot each day. These measurements give an indication of the degree of stomatal response to leaf water stress.

Drought Index

Transplanted trees which suffer water stress at the end of the dry season tend to lose most of their leaves, and flush rapidly after the first significant rains. Thus it was possible in February 1989, to score the proportion of all trees which had lost more than 50% of their leaves to derive a simple index which was principally relted to related to drought stress.

Phytophagus Insects and Phylloplane Activity

Damage from leaf-eating insects and accretions of leaf surface moulds and algae may reduce tree growth rates, and will certainly reduce assimilation rates when compared with those measured in healthy leaves (Table 2). Thus, a 4-level (quartile) 'phylloplane activity index' was devised to reflect the average proportion of leaf area per tree which had been lost by grazing or covered by algae.

RESULTS

Measurement of Residual Trees

In July 1989 the total 7 ha of treated and control plots contained 915 trees (>20 cm dbh) from 149 species, 114 genera and 39 families (Table 1). 50 commercial timber species (CENADEFOR 1985) were represented by 491 trees: thus the area is comparatively rich for secondary forest.

Diameter and distribution measurements show that the density of trees in the Manual and Mechanical Recru treatments is rather similar (122 ha^{-1} and 130 ha^{-1} respectively), and markedly less than in the control (200 ha^{-1}). However the average diameter of the trees left in the Mechanical Recru was larger than that in the other plots, resulting in a higher total basal area (26.1 m^{2} ha^{-1} of stems > 20 cm dbh) similar to that in the control (25.8 m^{2} ha^{-1}), but greater than that in the Manual Recru (21.8 m^{2} ha^{-1}) (Table 2).

Table 1. Most Common Species in the Mbalmayo Research Plots (7 ha, Jan 89)

Species	Family	Number (%)	Area-m^2 (%)
Celtis tessmannii	Ulmaceae	35 (3.8)	5.2 (3.3)
Alstonia boonnei	Apocynaceae	29 (3.1)	9.2 (5.7)
Pausinystalia pachyceras	Rubiaceae	26 (3.1)	2.6 (1.6)
Desbordesia oblonga	Irvingaceae	25 (2.7)	4.6 (2.8)
Terminalia superba	Combretaceae	23 (2.5)	7.3 (4.6)
Funtumia elastica	Apocynaceae	21 (2.3)	1.1 (0.7)
Eribroma oblongum	Sterculiaceae	21 (2.3)	5.3 (3.3)
Pycnanthus angolensis	Myristicaceae	19 (2.1)	2.4 (1.5)
Canthium sp.	Rubiaceae	19 (2.1)	3.1 (2.0)
Ricinodendron heudelotii	Euphorbiaceae	19 (2.1)	5.9 (3.7)
Coula edulis	Olacaceae	17 (1.9)	4.2 (2.6)

Canopy Closure

The average canopy closure observed using hemispherical-photographs followed the expected order: Control (92%) > Manual Recru (86%) > Mechanical Recru (76%) > Completely Cleared (59%) (Table 2). The comparatively high closure value recorded at the Completely Cleared site reflects side shading both from planted trees and from the shrub layer (mainly Eupatorium odoratum). This shading has less influence on total PAR received by the planted trees since the leaders are generally above the shrub layer.

The threshold value chosen to interpret grey scale values measured by the image analyser influenced the percentages recorded above, but never altered the relationship between treatments.

Temperature, RH, PAR and Red:Far-Red Ratios

Three-day means of air temperature and RH (Table 2) indicate that the Completely Cleared site had a significantly higher ($p > .05$) air temperature (27.4°C), and lower relative humidity ($p > .05$) (80.9%) than the remaining sites. Both the Mechanical and Manual Recru sites had higher relative humidities (98%), and lower air temperatures (23.7°C) than the Completely Cleared plot.

Three-day means of PAR were highest in the Completely Cleared plot (320 µmol $m^{-2}s^{-1}$) and lowest in the uncut plot (76 µmol $m^{-2}s^{-1}$). Measurements with these fixed sensors showed a higher mean PAR in the Manual Recru than in the Mechanical Recru. However, more detailed analysis (Lawson et al 1990) shows that the small number of sensors, variability in

total radiation between time periods, and differential shading from adjacent areas of uncut forest, combine to place doubt on the reliability of these data.

Two further sets of PAR measurements were obtained in February 1989 along transects through the treatment plots. The first was conducted over a 3-day period, with variable cloud conditions (Table 2). A second survey, was taken in the morning and afternoon of a completely cloudless day, but with only 2 rapid transects per plot. This complemented an earlier survey made around mid-day during cloudless conditions in July 1988 (Table 2). These data show that average PAR received in the plots follows the trend:Completely Cleared > Mechanical recru > Manual recru > control.

The ratio of red:far red light can be important factor in the stem elongation of young trees (Kwesiga & Grace 1986), and shows the same trend as PAR with a ratio of 1.33 in open sunlight, reducing to 0.85 in the uncut control.

G r o w t h o f P l a n t e d T r e e s

At the end of the dry season (February 1988), 5 months after planting, there were significant differences (p > .05) in the mortality of planted trees. This was higher in the Completely Cleared plot (16%) than the other two treatments (3%). Most of the early losses in the Completely Cleared plot are attributable to soil compaction and puddling in the rains, together with subsequent drought effects. However subsequent losses in this treatment were small, and by July 1988 its total mortality (19%) compared with 11% in the Mechanical Recru and 9% in the Manual Recru.

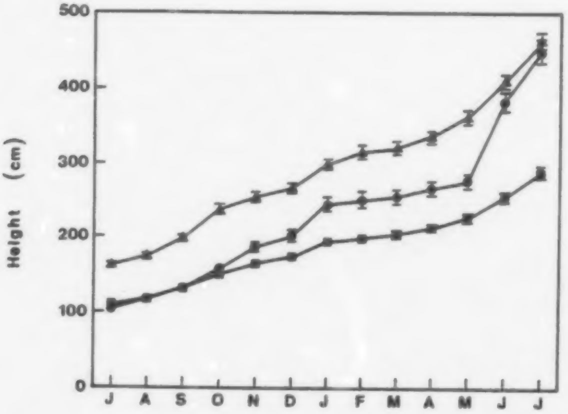

Figure 1: Average heights of planted T. ivorensis trees in the Manual Recru (■), Mechanical Recru (▲) and Completely Cleared (●) plots, from 11-23 months after planting Ngeh 1989.

Planted trees in the Mechanical Recru plot maintained a higher average height than the other treatments, until recently when the trees in the Completely Clerared plot started growing rapidly (Figure 1).

Assimilation Rate and Stomatal Conductance

Mean daily rates of assimilation, stomatal conductance and transpiration (Table 2) show statistically significant differences between all sites. The Completely Cleared treatment has the highest assimilation rate (8.2 µmol $m^{-2}s^{-1}$), and the Mechanical Recru the lowest (5.8 µmol $m^{-2}s^{-1}$). A similar, highly significant, trend was observed in stomatal conductance, and consequently in transpiration rate.

The relationship between gas exchange and PAR was modelled following Jarvis et al. (1985) From this figure it can be seen that assimilation rate is a linear function of PAR in the range 0-355 µmol $m^{-2}s^{-1}$. The slope of this line (0 apparent quantum yield) is a direct measure of the efficiency of light utilisation by leaves. This slope was steepest in the Mechanical Recru measurements (0.026), and least in the Completely Cleared plot (0.018), with the intermediate values in the Manual Recru (0.022). In contrast, the maximum rate of light-saturated photosynthesis (A_{max}) was highest for trees in the Completely Cleared plot.

Stomatal Conductance

Figure 3 demonstrates an initial attempt to explore the relationship between stomatal control and leaf water stress. The stomata of the trees in the Mechanical Recru plots were most responsive to water stress, such that stomatal closure was observed after only 2% fresh weight loss. In contrast, leaves from the Manual Recru did not demonstrate stomatal closure until 8% of fresh weight had been lost. Leaves from the Completely Cleared plot gave an intermediate response.

Drought Index

The Completely Cleared treatment exhibited the highest drought index (44% of trees with more than 50% leaf loss), followed by the Mechanical Recru (37%) and the Manual Recru (14%) (Table 2). These reflect the same trend as PAR and RH measurements, but are rather more marked, emphasising the need for future measurements of soil and plant water potential.

Phylloplane Activity Index

This index again appears to indicate the importance of water relations and relative humidity. The Completely Cleared plot scored lowest phylloplane activity (1.3), the Mechanical Recru was intermediate (2.0) and the Manual Recru scored highest (2.5) (Table 2).

Table 2. Summary of Meteorological and Physiological Factors (Ebogo site, planted Sept 87 - see text for details, ± standard error of mean)

	UNIT	Completely Cleared	Manual Recru	Mechanical Recru	Natural Forest
Meteorological Factors					
Canopy cover	%	58.5(±3.1)^d	85.8(±0.9)^b	76.3(±2.6)^c	91.9(±0.9)^a
PAR (spatial average)	µmol m^{-2}s^{-1}	300(±17.6)^a	149(±10.3)^c	224(±22.3)^b	-
PAR (sunny day July 1988)	µmol m^{-2}s^{-1}	1340(±90)	280(±50)	400(±62)	25(±8)
PAR (sunny day Feb 1989)	µmol m^{-2}s^{-1}	838(±42)^a	93(±27)^c	214(+28)^b	144(+39)^b
Red:Far red (3 day av.)	-	1.22(±.01)^a	1.13(+.01)^b	1.14(+.02)^b	-
Red:Far red (cloudless 2/89)	-	1.33(±0.1)^a	1.14(+.02)^b	1.12(+.02)^b	0.85(+.04)^c
Red:Far red (cloudless 7/88)	-	1.25	1.1	1.09	0.9
Air temperature	deg C	27.4(±.27)^a	23.7(±.1)^b	23.7(±.1)^b	24.5(±.02)^b
Relative humidity	%	80.9(±1.0)^c	98.5(±1.0)^a	98.0(±0.7)^a	89.4(±0.6)^b
Physiological parameters					
Mean assimilation rate	µmol m^{-2}s^{-1}	8.2(±.26)^a	7.8(±.26)^b	5.8(±.36)^c	-
Stomatal conductance	mmol m^{-2}s^{-1}	211(±4.0)^a	194(±3.2)^b	176(±5.9)^c	-
Transpiration rate	mmol m^{-2}s^{-1}	2.8(±.05)^a	2.6(±.07)^b	2.5(±.08)^c	-
Apparent quantum yield	-	.018	.022	.026	-
Drought index	% (note 1)	44	14	37	-
Phylloplane Activity Index	% (note 2)	1.27(±.05)^c	2.53(±.11)^a	1.95(±.17)^b	-
Crop and vegetation parameters					
Residual trees > 20cm dbh	number/ha	-	127	130	200
Residual tree mean dbh	cm	-	42.0	44.3	36.3
Resid. tree total basal area	m^{2}ha^{-1}	-	21.8	26.1	25.8
Weed biomass	kg m^{-2} (air d)	1.7(±.12)^b	2.1(±.19)^{ab}	2.3(±.23)^a	-
Planted tree height (12mths)	cm	130	130	190	-
Planted tree height (23mths)	cm	450	290	460	-
Planted tree survival	%	82	90	89	-

Note 1: Percent of planted trees having lost more than 50% of leaves at end of dry season.

Note 2: Percentage of total leaf surface on all trees/plot lost through insect grazing or covered by algae or mold.
'a', 'b' and 'c' superscripts indicate significant differences at $p > 0.05$ level (paired t-tests).

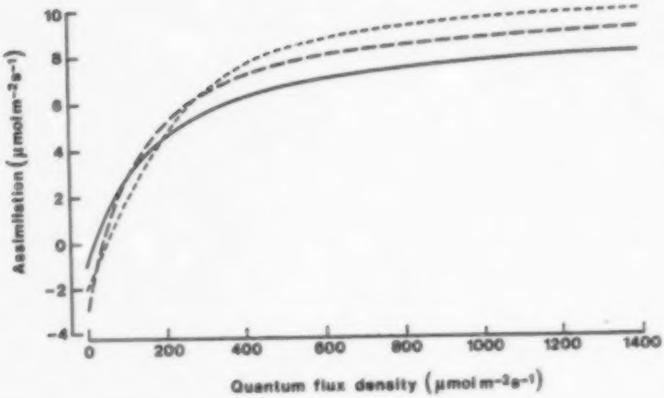

Figure 2: Assimilation/quantum flux curve fitted using method of Jarvis et al (1985) to field gas-exchange data. Completely Cleared (-----), Mechanical Recru (——), Manual Recru (— — —).

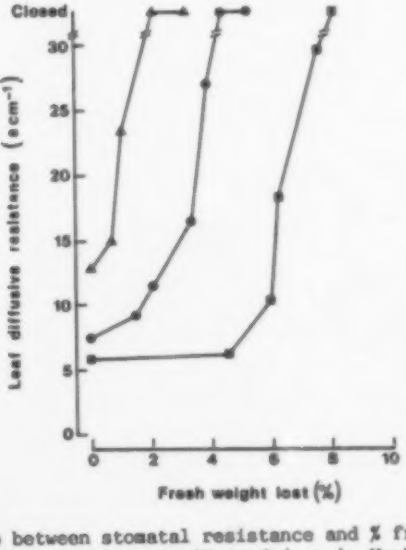

Figure 3: Relationship between stomatal resistance and % fresh weight loss from full turgor. Completely Cleared (●), Mechanical Recru (▲), Manual Recru (■).

DISCUSSION

Terminalia ivorensis is a light demanding species, and is an important coloniser of disturbed secondary forests. It is understandable therefore that trees in the Completely Cleared and Mechanical Recru plots should grow faster in response to higher levels of PAR on these plots. It is also reasonable that trees in the Completely Cleared plot should exhibit an adaptation to the high PAR levels by demonstrating the highest rate of light saturated assimilation. They also have the lowest incidence of leaf-coloniser activity, presumably because of lower relative humidity levels on this site, and higher direct PAR and hence leaf temperature.

. Planted trees on the Completely Cleared site showed highest mortality, largely induced by drought and soil compression, but the growth rate of survivors is now higher than on either of the other plots. This growth is likely to be in response to high levels of PAR, and the larger supply of available nutrients soon after planting, but it remains to be seen whether the overall loss of nutrients at this site will cause a later check in growth, as has frequently been observed in monocultures of Terminalia (Ofosu-Asiedu 1976).

The good establishment and rapid growth of trees in the Mechanical Recru treatment, shows that a limited amount of shade and soil-compaction will be tolerated by young Terminalia. Less effort and expenditure was involved in the clearance and maintenance of this plot compared to the Completely Cleared treatment, and it is likely that the trees will continue to grow rapidly provided that the overhead canopy is progressively poisoned.

The different site preparation techniques used on the 4 plots have effects which are not within the ambit of this paper, but which have consequences for the growth of planted trees and which may interact with micro-climatic effects (see Lawson et al 1990, Ngeh 1989, Musoko 1990).

- Soil compaction was greatest on the Completely Cleared plot (1.5 g cc^{-1}) decreasing through the Mechanical Recru (1.3 g cc^{-1}), Manual Recru (1.2 g cc^{-1}) and uncut forest (1.1 g cc^{-1}).
- Litter standing crop was greatest in the Manual Recru (11t ha^{-1}) because slash was left on the soil surface, whilst much less litter remained after complete clearance (3t ha^{-1}).
- Litterfall was highest in the control plot (81, 43, 39 and 9 g m^{-2} in the uncut, Manual, Mechanical and Completely Cleared plots respectively).
- Litter decomposition was slowest in the Completely Cleared plots.
- The Mechanical and Completely Cleared plots suffered substantial drops in P, K, Ca and Mg in both litter and soil within three months of clearance. This was attributed to leaching loss in rainfall.
- The method and extent of clearance had a marked effect on mycorrhizal spore numbers and species.

The higher rate of light saturated photosynthesis on the Completely Cleared plot indicates an adaptation to the higher light intensities prevalent at that site. These differences between sun- and shade-adapted trees in apparent quantum yield and maximum assimilation accord with other reports (Medina 1986). However, it is not clear why the A_{max} of leaves in the Mechanical recru plot should be lower than that measured in those from the Manual plot.

The apparent quantum efficiency of light utilisation by leaves, 0, proceeds in the order Mechanical Recru > Manual Recru > Completely Cleared plot. Chlorophyll content is a major cause of an increase in 0, and this is largely dependent on photon flux (Medina 1986). PAR therefore explains the order of the Mechanical and Manual Recru treatments, but not the low value of the Completely Cleared plot. Other factors such as nitrogen partitioning and availability, red:far red ratios and water stress are clearly important at this site.

It has been suggested that stomatal behaviour provides an integrated measure of plant water status, soil water status, evapotranspirational demand and growth history (Eamus 1987). Major differences have certainly been shown between plots, but it is unclear why there should have been reduced response to drought in leaves from the Manual Recru. There are two possible explanations: either these leaves can tolerate greater water deficits without incurring damage, or the stomata, because of the stable humidity conditions in this plot, have never required to develop an effective response to drought.

As clonal-forestry techniques develop in the moist forest zone of Africa it will become increasingly necessary to use cost effective silvicultural techniques which exploit the genetic potential of improved planting-stock. Wider-spacing will make it more important to avoid significant mortalities and growth checks, and it is therefore hoped that this type of study will contribute an understanding of the physiological reasons behind success or failure, rather than a simple record of growth rate.

There are several inadequacies of replication and sampling technique in the work described here. However, these plots, and more extensive ones established in 1988, are the precursors of a new ODA project on the regeneration and management of tropical moist forest in the Cameroon. This project will continue to monitor the factors identified as important for transplant growth and survival, and will do this in larger and better replicated plots.

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FOREST DECLINE AND GREENHOUSE EFFECTS HAVE THE SAME ROOTS

Wilhelm Knabe

Research Scientist and Member of Parliament

Previously State Institute for Ecology, Landscape Development and Forest Planning, D-4350 Recklinghausen
German Bundestag, Study Commission "Preventive Measures to protect the Earth's Atmosphere" D-5300 Bonn, FRG

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SUMMARY

Forest decline and green house effects are closely related. They have the same roots, show interconnected results and require a similar cure to avoid those detrimental effects. Their connections are obvious at various levels.

The driving chemical forces are gases, released into the atmosphere by man. Burning fossil fuels e.g. causes emissions of both the forest killers SO_2 and NO_x and the main green house gas CO_2.

Chemical emissions are only the by-products of economic forces which have changed our world. Our present economy is determined on one side by a growing need for energy and raw materials, on the other side by a decisive strategy of inventing and marketing new products. All activities are accelerated by the search for the most profitable use of the invested capital whereas no negative feed-back mechanism was developed in time to counteract environmental pollution and deterioration.

Economic growth certainly has psychological roots. The wish to live better than yesterday, better than other people or much better than our ancestors is a main stream concern.

Phytotoxic air pollutants and climatic changes are causing overlapping effects on forest ecosystems, e.g. because already weakened associations have partly lost their ability to adapt to stress. Hence countermeasures are urgently needed.

Forest decline and climatic hazards require the same medizine. The cure must begin in our heads. We have to replace old-fashioned strategies as high stacks and end-of-the-pipe solutions by new strategies which reduce the demand itself. Energy conservation and the replacement of fossil fuels by renewable forms of energy or recycling may serve as examples.

The scientific community of IUFRO has a great part in this dramatic play which decides on our future. Proper measures are explained in detail.

Keywords: Air pollution, forest decline, climatic changes, green house effects

INTRODUCTION

IUFRO is on its way towards global environmental protection. Environmental pioneers and pure economists cared for a development which was not free of contradictions. Some of you are witnesses.

At Oslo in 1976 key speaker Norman E. Borlaug (1976) harshly accused ecologists that their objections against his "green revolution" were responsible for the hunger in the world, and nobody, really no single person dared to support my critical response to the Nobel prize winner. But at the same Congress we listened Thor Heyerdahl's (1976) unforgettable speech on the nourishing and sheltering fruit forests of Fatu-Hiva in the Pacific Ocean and its barren sister island Motane ruined by men and sheep. We heard his warnings on those monocultures defended so much by Borlaug.

Ten years later in Ljubljana Russel Jim (1986) spoke on indigenous people as caretakers of the Earth and IUFRO first accepted that air pollution is not just a matter of specialists. Now, in 1990, the main threats of forest decline and climatic changes are brought together as one headline of the Congress. What a change. We have to define these terms however. Forest decline stands for the wide-spread deterioration of forest species especially in Central Europe and the Eastern United States which cannot be attributed to certain insects or biotic diseases. The scientific community at least in Germany explains this decline as a complex result of the impact of various air pollutants and interactions with biotic and abiotic stress. Green house effects are the sum of climatic changes caused by a general increase of global temperatures of the atmosphere and the oceans. They are explained by trapping infra-red radiation by gases which do not interfere with the incoming visible sun light but remit parts of the infra-red radiation sent from the earth's surface to space.

CAUSES AND SOURCES

Forest decline and green house effects have the same roots. That sounds more literary than scientific, but the facts behind are convincing. The connection was envisaged just two years ago by the German Greens(1). The relations can be seen at different levels.

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(1) Die Grünen im Bundestag: Klimaschutzprogramm 1988

The Scientific Aspect

Forest decline and green house effects can be explained by a scientific point of view. Both processes are then regarded as the result of trace gases emitted into the atmosphere by man. These trace gases interfere with the functioning of complex systems, the plant and animal associations living in a forest or the even more complex pattern of climate with its cycles of water oxygene and carbon dioxide with its fluxes of radiation and heat. The temperature close to the surface is kept at a global mean of +15°C instead of -19°C = 254 K by the presence of certain trace gases and water vapour in the atmosphere under natural conditions. Only the additional warming by artificially introduced gases is regarded as the detrimental green house effect. The contribution of the various gases is fairly well calculated in the case of climatic changes. Ramanathan has made a reasonable and fairly wide accepted guess (Table 1).

Table 1: Contributions by the various gases to the additional green house effect in the 1980(Ramanathan, according to German Bundestag 1989)

Greenhouse gas	Estimate in per cent (%)
CO_2	50
CH_4	19
CFCs	17
Ozone	8 *
N_2O	4
Stratospheric water vapour	2

* This figure is a global mean value. It should be higher in the Northern hemisphere and lower in the Southern Hemisphere.

Let us look at the main green house gas CO_2. Fig. 1 shows the trend of CO_2 concentrations during the last 25 years. One can spot both the general increase of concentration and the annual variations caused by the fixation of carbon in summer and release of CO_2 in winter of the Northern hemisphere. The original pre-industrial concentration of CO_2 is assessed to only 280 ppm. While the green house gases except of ozone are not toxic and act just by their physical behaviour, those gases which are responsible for forest decline are phytotoxic or change soil properties to the unfavourable side. The contribution of the individual gases to forest decline however is much more difficult to assess.

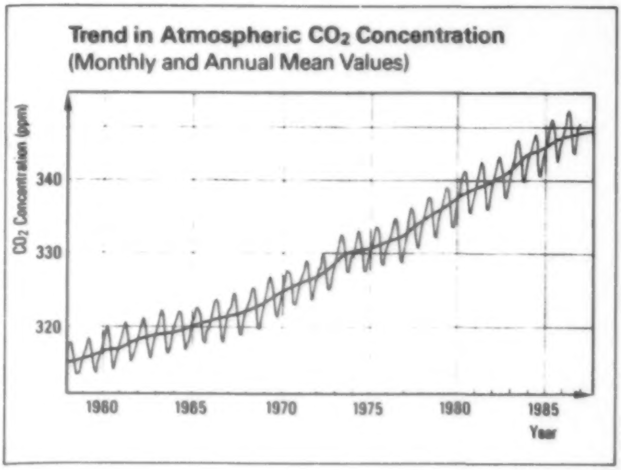

Figure 1: Monthly and annual mean values of atmospheric CO_2 concentrations (in ppm) measured since 1958 at the Mauna Loa Observatory, Hawaii (German Bundestag 1989).

We only know from history that sulfur dioxide (SO_2) used to be the main toxicant from the beginning industrial revolution closely related with the smelting of sulfidic ores and the burning of sulfur containing coal. Also related with SO_2 was the extremely phytotoxic hydrogen fluoride in those days because both the smelted ores and the burned coal also contained fluorides. The relation between F and S in coal, e.g., reached with 1:100 about the same dimension as its difference in toxicity.

Oil has replaced coal as main fossil fuel in must industrial countries since the sixties; especially driven by an increasing fleet of motorcars. This caused a change in the composition of air pollutants. SO_2 became only number 2 behind nitrogen oxides (NO_x), because sulfur was removed from crude oil in the refining process and the higher temperatures of the combustion process by which the strong double binding of N_2 is broken and nitrogen oxides are formed. The primarily formed NO however is no stable compound but the starting point of various chain processes of atmospheric chemistry where ozone (O_3) as main toxic component is formed under the influence of sun radiation.

The Double Attack of Air Pollution on Vegetation

Vegetation is affected by air pollution on at least two different pathways (Knabe 1985).
- Direct effects on overground plant parts
- Indirect effects on plants by soil changes and by impact on roots (VDI 1983).

One might add a third way:
-Changed disposition of host plants to parasites and lowered resistance to abiotic stress - forst, heat, wind, e.g..

Direct Effects of Air Pollutants on Overground Plant Parts

Plant leaves are surrounded by their skin, which protects them against water loss and contact with toxic dust and gases. Only marginal amounts of air pollutants can penetrate an intact leaf surface. Most gases find their way into the plant through small natural openings, the stomata which usually are located on the lower leaf surface. Stomata open in the morning and usually close at night this controlling CO_2 uptake and the rate of photosythesis as well as stomatal transpiration, that is, water loss. Toxic gases have a chance to enter the leaf via the same stomata which are opened for the necessary gas exchange. Water soluble gases like SO_2 are then dissolved in the water-soaked cell walls and transported by the flowing water or just by diffusion to the cell interior, reaching the protoplasm and the green chloroplasts. SO_2 and other pollutants interefere with plant metabolism in various aspects, the results perhaps being reversible depression of photosynthesis or irreversible necrosis of tissue. If larger parts of the plant are killed, the plant may die.

Indirect Effects on Plants by Soil Changes and by Impact on Roots

Plants usually root in those soils which are appropriate to their demands with regard to soil reaction, nutrient, water, and air content. These conditions can be changed by air pollution. The soil may either become more acidic by deposition of acid gases, dust, and rain or be made more alkaline by basic dust around lime quarries or cement plants. The change in soil conditions might reach an extent which will cause the dying of fine roots, leading to the degeneration of larger roots (Wieler, 1905. 1933; Ulrich et al., 1983). Windfall of trees, withering of plants or changes in plant associations may be the result. Figure 2 is explaining a small part of the possible interference.

Changed disposition and resistance

The ability of a plant to withstand the attack of parasites and plant diseases is strongly dependent on its vigour. Weakened trees are more successfully attacked by bark beetles and pathogenic fungi like Armillarea mellea (Schnaider and Sierpiński , 1968). Also trees that have been exposed to SO_2 are less tolerant to frost or low temperatures (Materna, 1974).

Multiple Sources

The real connection between phytotoxic air pollutants and green house gases is established by their sources. Most of them release both kinds of components at the same time. Burning fossil fuels causes emissions both of the forest killers SO_2, NO_x and in the case of coal HF and the main green house gas CO_2. Theses gases differ in quantities by large and act in different ways but they are released at the same process, the oxidation of material

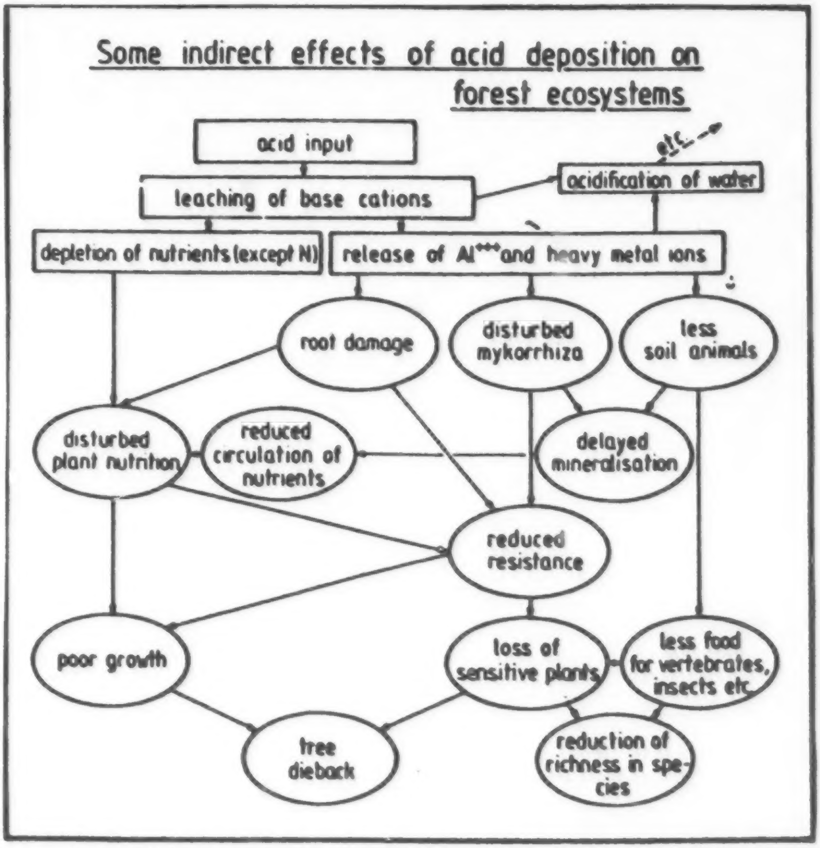

Figure 2: Possible effects of acid deposition and soil acidification (Knabe 1983). ▭ = Impact of physical environment, ⬭ = Effect on biotic community

formed under anaerobic conditions as stored solar energy. Mass concentration of life stock and applying vast quantities of nitrogen fertilizers is detrimental to surrounding forests through NH_4 and the climate by the green house gases methane and N_2O (not NO_2).

The organic manure of life stock is developing methane under anaerobic conditions. One additional methane molecule is 32 times more effective in trapping infra-red radiation than one additional CO_2 molecule, however average life time

is only about 10 instead of 100 years as CO_2. The same anaerobic process is releasing NH_3, which has amphoteric character. NH_3 is neutralizing weak acids in a rain droplet by the sum reaction $2\ NH_3 + H_2SO_3 \rightarrow (NH_4)_2SO_3$.

But the same quantity of acidity neutralized in rain is released to the soil if an ion of NH_4 is taken up by a plant root. Nitrous oxide (N_2O) is 150 times more effective as green house gas than CO_2 on a molecular basis. Its lifetime in the atmosphere is however not shorter as that of CO_2 but 50 per cent longer. It amounts to about 150 years. The steady man-made increase of N_2O at annual rates of 0.2 to 0.3 per cent is attributed mainly to increased use of N-fertilizers. This is however typical for the industrialized form of agriculture with its high inputs of energy and pesticides which are also regarded co-factor of forest decline.

There we come to the third multiple source chemical industry, especially the chlorine chemistry. The production and use of chlorinated hydrocarbons cause both environmental contamination by phytotoxic substances and ozone depleting CFCs, which are remitting infra-red radiation 15.000 times more effective than CO_2 while their life times are similar.

The Economic Base of Pollution

Chemical emissions are only the by-products of economic forces which have changed our world. Our present economy is determined on one side by a growing need for energy and raw materials, on the other side by a decisive strategy of inventing and marketing new products. The latter activity increases the demand. Millions of managers, clerks or politicians are only sitting and thinking, what could we produce else, where can we sell more and how can we earn more. This innovation process has changed the world, had brought also many positive changes but has eaten up our natural resources.

All activities are accelerated by the search for the most profitable use of the invested capital whereas no negative feed-back mechanism was deveoped in time to counteract environmental pollution and deterioration. Let me show one example. When industrial production started, dying trees in the close surrounding appeared as warning signs and could have resulted in an immediate negative feed-back mechanism against unlimited pollution and growth. However then the high stack was invented. High chimneys dispersed the concentrated air pollution into greater heights far above the heads and trees of the neighbours who only would have had a title to demand for compensation. So liable operators were prevented from being identified, the victim in a forest mountain far away could not find the cause or source of the damage, the public did not become aware of the problem. It needed the death of thousands of Scandinavian lakes to get alarmed and it required further 20 years before proper actions means of air pollution control had success. Hence, high stacks were properly called 'man's trick to avoid liability' (Knabe 1985). Here we see the basic failure of modern economy.

Economic growth, profitable production and a stable currency are regarded as main criteria for a sound economy. The necessary ecological account was neglected or developed only in a rudimentary form. It is time to change.

Psychological Roots

Economic growth certainly has also psychological roots. The wish to live better than yesterday, better than other people or much better than our ancestors is a main stream concern today. That has not been the case in all times. Heyerdahl (1976) describes the early Polynesians at Fatu-Hiva and their life philosophy entirely different from ours:

> "They were ancestor worshippers and venerated their own predecessors to the extent that they wanted to copy them in every respect and to abide by the customs and living manners successfully practiced by them. For this reason the Polynesian tribes were not at all progressive, they were fully satisfied with an established survival pattern as long as it fulfilled their daily needs and aspirations. They strived for permanence rather than for progress. They had no cash economy and no admiration for wealth. They reared no more pigs or chickens, planted no more crops, and caught no more fish than what would be needed for decent, daily family survival. ... In consequence of this, the Polynesians never exploited any form of monoculture, each family grew only the number of trees and planted only the quantity of root crops they would need for their own consumption."

The Polynesiens stood not alone in their care for nature. Russel Jim(1986) spoke for the Yakima Indians in Washington State at the IUFRO World Congress in Ljubljana. I feel we Europeans and white Americans can learn a lot from them to survive.

OVERLAPPING EFFECTS

Forest decline and climatic change have still another connection. There are the overlapping effects between air pollution and climatic change.

Figure 2 has shown some of the chain processes within a forest ecosystem. Many of them are enforced by climatic changes. We already know that a general warming of the troposphere is connected with greater climatic variations and anomalies. Hence extreme droughts, thunderstorms, hurricanes or gales will occur more often and more severely. And these events will meet the trees more vulnerable, less resistent than previous generations because their needle mass is already reduced by air pollutants, their roots affected by soil acidification and their frost hardiness decreased by nutrient

imbalance between nitrogen and potassium. The Iceland depression and the anticyclone of the Azore Islands have already become stronger in opposite direction within the last 20 years and that created a general increase in wind speed. It can easily be accounted that this means more windfall. The salt spray will spread further inland and leaves with cuticles damaged by ozone would suffer more severely from this salty impact.

Climate itself may also be influenced by forest destruction. Large scale breakdown of forests as result of regional and global air pollution would convert the safe carbon stockpile of biomass into climatic relevant CO_2 in the atmosphere, thus accelerating the green house effect.

COUNTERMEASURES

Countermeasures are necessary. New strategies to control green house gases were proposed at the 8th World Clean Air Congress 1989 in The Hague(Knabe 1989). They have also great importance to reduce phytotoxic air pollutants. New methods are needed because the traditional methods fail to solve the problem.

Traditional Methods inadequate

The widely used principle of dilution does not help anything against global greenhouse gases. High stacks - blamed as man's trick to avoid liability in the neighbourhood - appear as nonsense in this respect. The height of emission has no importance at all for all gases with a high lifetime.

The purification of waste gases has been the other strategy world-wide applied to control air pollution. But also this method is inadequate so far green house gases are concerned. CO_2 is too huge in quantity to be removed and CFCs are too inert to react. Besides that they usually end up in solid waste or polluted water.

New Strategies are Needed

Energy consumption as a key

It should be mentioned that the relation between energy consumption and air pollution was already described 25 years ago. Hepting (1964) first differed between the air pollution of the past, localized at certain single smelters or coal fired power plants and characterized by its main component SO_2, and the upcoming regional photochemical air pollution with ozone as main component. He saw this as result of increase in energy consumption and the change in fossil fuel mix. Then Knabe (1966) stimulated by Hepting made the first quantitative assessment and proposed the coming forest decline from the curves of energy growth. That meant limits of growth, but nobody cared about years before the Club of Rome came to the same conclusions. The great difference in energy consumption on a state basis is shown in Figure 3.

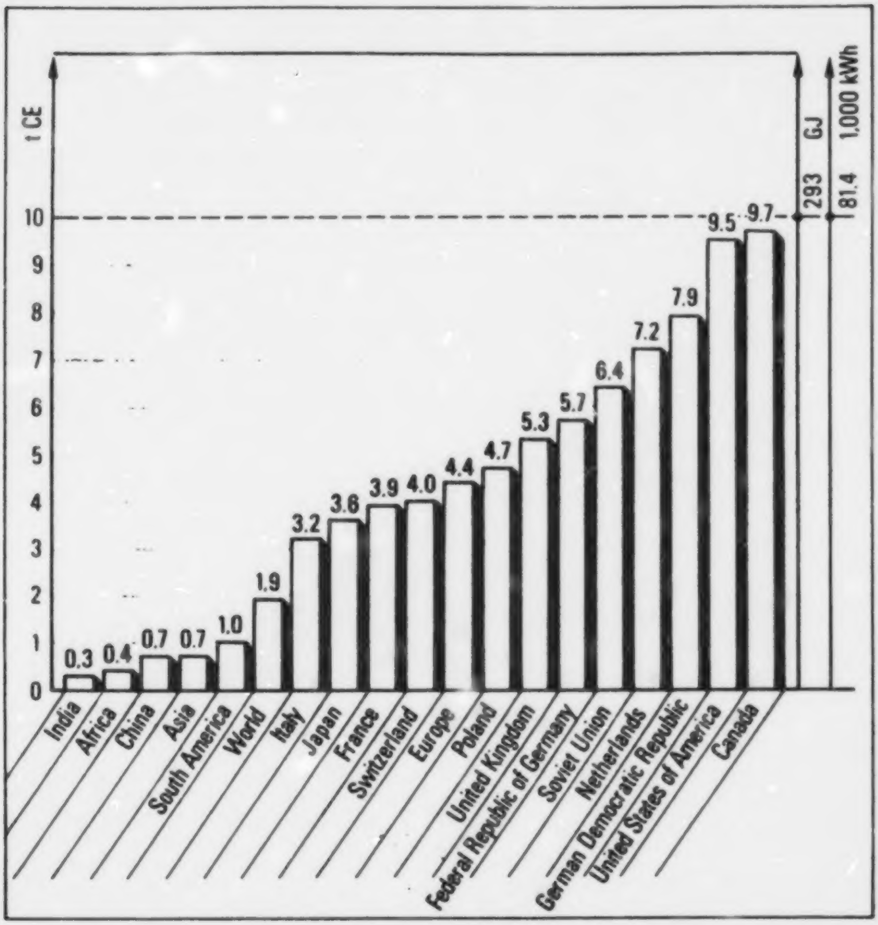

Fig. 3: Per-capita primary energy consumption in 1986 in various countries and continents, as well as worldwide.

Data are given in tonnes of coal equivalents (t CE) (left-hand scale and figures at top of bars), as well as in gigajoules (GJ) and 1,000 kilowatt-hours (1,000 kWh) (right-hand scale) (8).

One can see that the United States use per capita 30 times more enrgy than India. And a poor Indian peasant may use even only a tenth of this amount. The World Conference on "The Changing Atmosphere" held in Toronto in late June 1988 recommended that world wide CO_2 emissions should be reduced by 20 per cent by the year 2005, and by at least 50 per cent by the middle of next century (Conference Statement 1988). These global figures mean that the industrial countries must enforce their efforts much stronger than the rest.

New strategies, not merely new technologies are required to achieve this goal. We need environmental concerned technical innovation, e.g. the replacement of fossil fuels by renewable energy. We need new economic strategies like the least cost planning principle which has changed the attitude of many American power companies. We need administrative measures and social campaigns. They must give the base for inevitable political decisions until the verdict of CFCs or products which endanger the planet by comparable risks.

The tasks of IUFRO

The scientific community of IUFRO has a great part in this dramatic play which decides our future. Scientific informations are needed in many fields. Table 2 shows some possible activities of agriculture and forestry either to reduce emission rates or to increase carbon in biomass and soil. All of them would need hundreds of scientists in many countries in order to have success.

Table 2: Control of Green House Gases in Agriculture and Forestry (Knabe 1989)

Strategy - Measure	Effect
Reducing emission rates by	
-stopping deforestation and burning	---->less CO_2 and other gases
-reduction of energy input	
-reduction of lifestock or meat consumption	---->less CH_4
-reduction of nitrogen fertilizers	---->less N_2O
Increasing carbon in biomass and soil by	
-organic farming and humus enrichment	---->less CO_2
-afforestation	---->less CO_2
-increase of standing timber	---->less CO_2
-organic waste disposal without control of CH_4	---->less CO_2, but more CH_4
-organic waste disposal with use or control of CH_4	---->less CO_2

Some special tasks should be emphasized. The preservation of the tropical forests is an utmost 'must' in this connection. The further development of agroforestry decides on the future of many rural regions. The knowledge on forest ecosystems and its behaviour under natural and anthropogenic stress

is important as that on methods to increase their vitality and stability. The cooperation of forest scientists with other disciplines has to be improved e.g. with climatologists, stastisticans, sociologists and futurologists. The same is required between the forest scientists of the developed and developing countries.

Finally, we need strategies for survival. All of us can learn from forests and trees, which have survived for centuries or even millenia. You foresters could explain this to politicians. But we already know: Our planet cannot be saved without social justice between North and South.

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HYDROLOGY OF FOREST DECLINE IN RELATION TO AIR POLLUTION

Josef Křeček

Institute of Applied Ecology
Agricultural University of Prague
Czechoslovakia

FDC: 116.31: 425.1: 425.3

SUMMARY

The changes of streamflow characteristics influenced by air pollution effects on spruce forests in the upland humid temperate areas of Czechoslovakia are analysed here. The small watershed approach was used to determine a hydrological impact, quantity and quality, and compared with the results of standard network and historical investigations. According to an intensive development of herbaceous vegetation with the forest decline, only a water yield increase in range of 5 percent was observed. From the investigation of historical events the summer rainstorms are considered to be a predominant origin of the catastrophic floods have been registered there in the past. On the experimental basin the summer peakflows not exceeded a periodicity of one year, an increase in range of 8-10 percent influenced by the forest logging was estimated. More important pointed out the snowmelt floods during the end of spring there. A decrease of low flow of 355 days-duration about 18 percent has been observed. The annual total deposition of nutrients on an open field of the investigated uplands was about 40 tons per sq. km during the last ten years. A deposition increase of 30-40 percent was observed under the canopy of experimental forest. Both precipitation and streamwater there are almost always acid with pH bellow 5. A permanent overexceeding of limits given by the Drinking Water Standard was evident in the treated water of the investigated adjacent waterwork for the indicators: pH, maximum contents of ammonium, aluminium, manganese and humin acid, and minimum sum of contents of calcium and magnesium.

Keywords: Air pollution, forest decline, streamflow

INTRODUCTION

Hydrological conditions influence the socio-economic development of the country. One of the most important tasks of hydrology is to provide information for the rational use and development of water resources. While humid temperate areas are characterized by large supplies of water, pressures on water resources can be here very high due the large variations over space and time and the intensive human influences. Because of prevailing streamflow in the water budget of Czechoslovakia and water quality problems in recent years the supply management technique there tends to reservoirs planned in headwater areas, least developed parts of the river basins. But pollution from non-point sources such as the atmospheric deposition is currently the focus of concern there. The air pollution due to the burning of fossil fuels and its effects on environment of these mostly forested areas (deposition, forest damages, commercial forest logging, deforestation, climatic changes in probably global warming and increase of winter precipitation and summer evapotranspiration) tends to increase of resource variability in space and time and water pollution there. The solution of these aspects is influenced by economic and possible political conditions. In the beginning of eighties was evoked an idea of possible reduce this impact due any effective forestry practice. It considered start of a detailed study on hydrology under the air pollution damage effects.

AREA DESCRIPTION

Conservated Headwaters

The water conservation strategy on national scale in Czechoslovakia is given by the Water Law (No. 137/1973). This law respect three main institutes of protection: Conservated Headwaters, Rivers of Drinking Water Intake and Sanitary Buffer Strips. The system of Conservated Headwaters is considered to be most important part of this strategy because of including a great part of the other two other institutes and aspect of a total regional control against a negative man's impact on water resources. By the declaration of National Government in the years 1978 and 1979 were established in Bohemia and Moravia (western parts of Czechoslovakia) 13 units of Conservated Headwaters extending over an area of 6 811 sq. km (Figure 1). These mostly mountain or hilly regions are forested, Norway spruce (Picea abies, (L.) Karst.) is the predominant tree of the forest there.

A multi-purpose forest management idea in these areas considered 16 percent of the whole forest area in Bohemia and Moravia. This concept was expressed by prohibition of forest

Figure 1: Scheme of the units of Conservated Headwaters in Bohemia and Moravia ($48^{0}30' - 51^{0}N$), 1-Ore Mountains, 2-Jizera Mountains

land reduction by more than 24 hectares in the individual treatments and 500 hectares in the whole headwaters unit. It is also forbidden to drain forest land in the extent exceeding 250 hectares in a headwaters unit. Unfortunately in the time of Conservated Headwaters declaration the great part of spruce forest in the Ore Mountains (1 470 sq.km) was heavy damaged or harvested already and also important damage of spruce cover in the Jizera Mountains occured. Contemporary about 60 percent of forests in the Conservated Headwaters there are damaged, dead or logged due the air pollution impact. Therefore the idea of multi-purpose forest mangement proclaimed by the Conservated Headwaters is of any formal importance only.

The mentioned headwaters are characterized by humid temperate areas with predominantly maritime influences with westerly movement of humid air masses. These areas have good developed surface runoff system and mostly 'endogenous conditions' in catchments. The resistant acid crystallinic bedrock and relatively shallow and pure glay-podzols determine a very limited storage capacity of the catchments and natural acidity of the runoff. The elevation reaches 800 - 1 600 m, average annual temperature of air 4 - 6 ^{0}C and annual sum of precipitation in longterm scale is 750 - 1 600 mm. An extensive upper plane formation is evident there. The natural vegetation of these areas were broad-leaf or mixed broad-leaf and coniferous forests. Particularly during the past century these forests were replanted by spruce seedlings.

F o r e s t r y   d e c l i n e

A start of an important occurence of air pollution in Czechoslovakia is coupled with the use of coal power stations in eastern countries after the second world war. The today's annual amount of emissions produced in our country is given in Table 1. The contemporary monitoring of air pollution here is not sufficient to draw conclusions about an exact emissions exchange in space or time, so much the more that till now the components of sulfur were widely observed only. It is assumed that probably about one half of the sulfur deposition here originated from foreign emission sources and about 40 percent of our sulfur emission total is deposited here. The main source of emissions in our country is industry (68 percent of the emission total). Therefore the average daily concentration of sulfur dioxide 2.5 mg/cub.m in industrial areas of northern Bohemia much overexceeded the allowable limit of 0.15 mg/cub.m.

Table 1: The contemporary annual total of emissions into air in Czechoslovakia (Hraško 1987 in Křeček 1988)

Area	Amount of emissions (mil. tons/year)			
	Solid	SO_2	NO_x	CO, C_xH_y
Bohemia and Moravia	1.2	2.3	1.0	1.7
Slovakia	0,4	0,6	0,2	0,5
Czechoslovakia	1.6	2.9	1.2	2.2

During the sixties was proved the influence of air pollution on spruce forest damages observed here. During the year 1971 was made the first systematic evidence of the visible damage effect and this evidence periodical continues. All prognoses of a progress in forest damages and logging given in seventies (Materna 1978 in Vitha 1979) were during the next period quite overexceeded by the actual course. The evidence of damage effect on coniferous forests in Bohemia and Moravia at the present time is given in Table 2. The whole area of forest land there is 23.8 thousands sq. km with a probably amount of 513 millions cub. m timber volume. The total area of observed damage effects on coniferous forests is about of 10.49 thousand sq. km (e.g. 44 percent of the forest land in Bohemia and Moravia), where probably 40 percent of this area was harvested already. A loss of timber production there (due the destruction of trees, decrease of growth rate and age of rotation, and a conversion to decidous trees) was considered to be about 2.3 millions cub. m of wood in the year 1986. Unfortunately this fact about a timber production decrease is till now only one aspect of practical socio-economic solutions there.

Table 2: The contemporary area of coniferous forest in Bohemia and Moravia with a remarkable air pollution damage effect (Henžlik 1987 in Křeček 1988)

Damage categories (% destroyd trees)	0	1-5	6-30	31-50	51-70	71-99	100
Extent area (thousands sq. km)	5.32	3.56	1.17	0.31	0.06	0.04	0.03

The direct air pollution damage effect in headwater forest is raising by some insect epidemies and commercial logging. The intensive clearfelling on the mountainous slopes contributes to danger of soil erosion. The flutes on skidroads and truckroads are important source of erosion and sedimentation.

METHODS

P r e d i c t i o n o f e x p e r t s

The first interest about the influences of forest decline on hydrological regime in Czechoslovakia was dated in 1978, where the Ore Mountains Region came to the focus of water management concern. The apprehensions of floods occurence in surface coal mines on foot of the mountains iniciated discuss about an increase of high water parameters due an expected change in forest cover. The necessity of a fast solution of the problem and a short of suitable hydrological data from this region allowed to accept only the method of 11 experts predict. For given time levels were made prognoses of forest development and for this scenario the hydrological parameters evaluated. The peakflows, flatwaves volumes and water yield (mean annual runoff regime) were in concern of this study (Vitha 1979). The method of Curve Number proposed by U.S.Soil Conservation Service to predict runoff parameters for a certain soil-vegetation complex, empirical equations using a parameter of forest percentage in basin and also experiences from some detailed studies in different regions were mostly taken into account.

N e t w o r k a n a l y s i s

The problems of unsufficient data of existing precipitation and runoff gaging network (unstable measuring profiles of streams, unsufficient observation technique) discovered during the period of experts prediction (1978-1979) initiated the

reconstruction of existing gage network in the headwaters here. In 1982 started operation of the authomatic data collection network of the Enterprise Ohre River Basin in the Ore Mountains using 216 measured variables (water level, precipitation sums, air and water temperatures) on the 79 field stations. But in contrary to the progress in data collection system the hydraulic problems of many registered profiles remained. Similar at the same time organized the Czech Hydrometeorological Institute an added network of 6 runoff gages in the Jizera Mountains considering basin's area of 2-26 sq. km with standard technique of observation. Water chemistry there was observed only in the profiles of waterworks, on drinking water reservoirs.

Experimental basin

To make a progress in genetic hydrology on the field of forestry decline the approach of small experimental basin started in the Jizera Mountains in 1981. The Jizerka Experimental Forest consists of two adjacent basins, which area is 0.37 and 0.54 sq. km. At the origin the studied basins were fully forested with Norway spruce of an average age 90 years and about 20 percent of trees in average has been strongly damaged already. After a calibrated period 1981-1985 one basin unit was cleared during 1986-1988. Unfortunately it was not possible to keep the other basin in an exact 'controled phase', a cut of 25 percent area was necessary due an insect epidemy. Four raingages located in forest clearings were observed there to estimate the average depth of precipitation over the studied area. Stream discharge is measured by the sharpcrested weirs mounted on weir boxes with the continuous water-stage recorder. The micrometeorological observation (vertical profile of air temperature and humidity, precipitation throughfall under the canopy) has been used to estimate an actual evapotranspiration. Water samples have been obtained weekly by grab sampling, with some additional sampling during storm period. As the plastic funnels of rainfall and crownwash sampling have been exposed permanent, the precipitation loadings stand for a measure of total (wet and dry) deposition.

Remote sensing

A macro-scale remote sensing has been used periodical (one or two years intervals) to register an actual course of cleared area and erosion flutes in the Jizera Mountains. The images in band 6 (near infrared) have been made from aeroplane in height of 3 thousands m and manual analysed. In a micro-scale a remote sensing method was developed using albedo measurement from helicopter in height of 40-60 m and the images in band 7 (near infrared) taken from a model aeroplane flying

lower than 200 m above the soil surface. The aim here was to extrapolate the transpiration estimates. These images selected after the visual evaluation were analysed on the Photomation 1700 drum scanner and the optical density in the range of 0-255 grey levels obtained in a digitalised form. The remote sensing was provided in summer cloudless days.

H i s t o r i c a l   i n v e s t i g a t i o n s

The observation period is an important factor of the hydrologic studies. For the peakflows probability estimates from relative short observed data series has been widely recommended an approximation by the log-Pearson Type III distribution or the first asymptotic distribution of extreme values, commonly called the Gumbel distribution (Linsley 1975). The difficulties of this method arise by a small basin, where the flood regime is of greater variability and assymetry. In this way it is possible to analyse a forest impact on peakflows of shorter recurrence interval only. Therefore it is helpful to objectify some peakflows occured in history from the archival data of flood catastrophes.

RESULTS

W a t e r   y i e l d

Mean annual discharge series

According to the prognos study (Vitha 1979) 15 percent increase of longterm mean annual runoff due a forest decline effect was expected in the Ore Mountains during eighties, e.g. for an average: precipitation P=900 mm, runoff R=500 mm, runoff increase dR=75 mm. Negligible change of variability and assymetry of mean annual discharge series was assumed. From an analysis of discharge in streamgage network of the Jizera Mountains during 1982-1986 Bubeničkova(in Křeček 1988) reported nonsignificant trend in water yield according to about **forest** destruction on 30 percent of basin area. On the contrary Wozniak (in Křeček 1988) found 150 mm increase of longterm mean runoff in the Polish Jizera Mountains (Figure 2). A total runoff increase of 31 mm (3.8 percent) during the experimental phase of clearcut at Jizerka basin (1986-1988) was analysed.

Energy budget

The latent heat flux estimates using Bowen method contributed to an idea of greater evaporation losses in the Jizera Mountains than they were considered from precipitation-runoff balance.

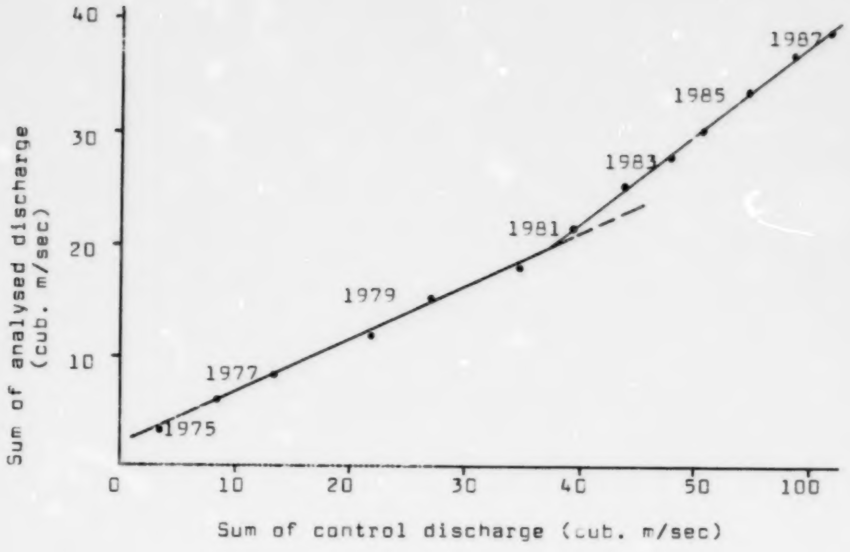

Figure 2: Double-mass analysis of water yield increase after spruce forest decline and harvest, basin of Kamienna River at Jakuszyce (Wozniak in Křeček 1988)

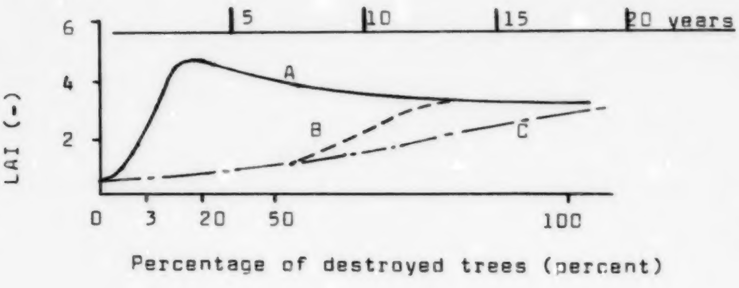

Figure 3: Effect of spruce forest harvest on development of herbaceous vegetation in the Jizera Mountains, A-clearcut before the damage phase. B-clearcut in time of 50 percent strongly damaged trees. C-without clearcut

This idea was confirmed there by the detailized water balance study. The mean annual evapotranspiration was found about 530 mm during the calibration period of the Jizerka basin, where interception loss was a predominant component (65 percent). Therefore a significant increase of water yield after the forest harvest here is reasonable to expect.

Conceptual water yield model

To explain the origin of different results in water yield change presented before the conceptual model Brook (Federer and Lash 1978) was accepted. The relative dense herbaceous vegetation on the experimental basin (Calamagrostis villosa-65 percent and Avenella flexuosa-32 percent) with mean leaf area index (LAI) in summer of 3.26 seemed to be a main reason of the event observed. In Figure 3 is given the course of herbaceous LAI for three different forest practices (A-harvest of 'health forest', B-harvest of damaged forest, C-course of forest damage without any treatment). The water yield increase output from the Brook model dR for these variants: dR_A=160 mm, dR_B=62 mm and dR_C=35 mm. For the fourth year after the harvest of 'health forest' no increase of water yield could be observed due a rapid growth of grass where the summer herbaceous LAI is of 4.5.

F l o o d r e g i m e

The prognosis of experts recommended for technical project in the Ore Mountains to respect an increase of peakflows and flood volumes per every 10 percent of spruce forest reduction, 10 and 4 percent respectively. The short runoff data series we have in headwaters are not sufficient to do any verification of the prognosis yet. From the investigation of archival data of floods in basin of the Jilovsky River (area of 76 sq. km), Figure 4, it is evident the shortness of 30 years runoff observation for exact flood frequency curve extrapolation. During eighties than the authorization of the 'historical' frequency curve was fully confirmed by occurence of two flood events their return period according to the theoretical curve would be about of 2000 years. From the history of the Jizera Mountains it is evident that most of catastrophic flood events registered in archives originated in summer period from storm rainfall. For example in the profile Frydlant on the Smeda River (area of 132 sq. km) have been registered 33 floods occured during the last 600 years, only two originated from a snowmelt combined with a warm rain event at the end of spring. The other were observed during July (14), August (10), September (4) and June (2). In the experimental basin Jizerka an increase of summer peaks not exceeding return of one year was found in range of 8-10 percent.

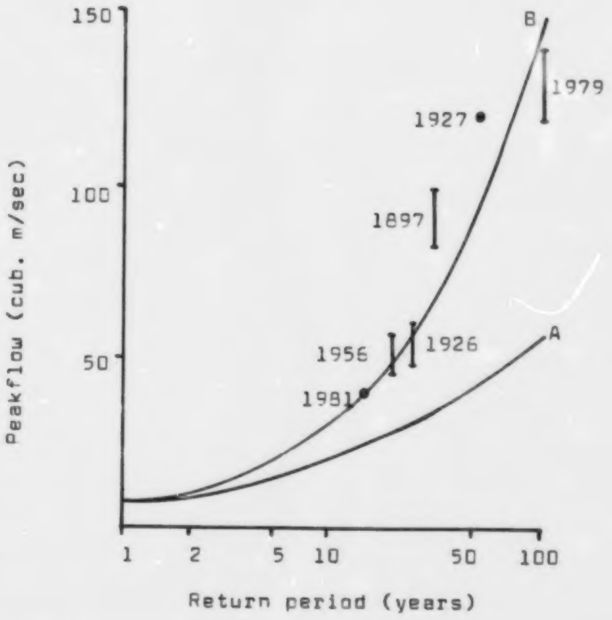

Figure 4: Flood frequency curves for the Jilovsky Potok river in the Ore Mountains, A-approximation of 30 years observed data by theoretical distribution Pearson-III, B-using investigation of archival floods (Vitha 1979)

W a t e r   Q u a l i t y

The annual total deposition of dissolved material on an open field of Jizera Mountains upper plane (Jizerka station) is about 40 tons/sq. km, sulfate (43 percent), nitrate (21 percent) and chloride (9 percent) are predominant components there. An increase of 30-40 percent this depostition was observed under the canopy already damaged spruce forest. Both precipitation and streamwater at Jizerka are almost always acid with pH below 5. an average of 3.9. The sulfate export in streamflow corresponds with the process of direct runoff, the mean annual concentration of sulfate in runoff is in range of 15-20 mg/l. Nitrate annual export or peak values in runoff did not menace the drink water limit. The nitrate export is only about 18 percent of the deposition, affected by an intensive grass cover uptake. The annual outflow of aluminium amounted nearly to its deposition. The aluminium concentration increased rapidly

during the summer storm events where a maximum of 5 mg/l was observed. A significant increase of humin acid concentration in streamwater from 0.8 to 10.5 occured after the clearcut. The erosion of soil increased from 0.01 to 1.4 mm after the forest harvest due a flute erosion on truckroads and skidroads. The sediment loss in runoff was observed in range of 1/12 - 1/3 of eroded volume according to the position of flutes in basin. In the treated water ofiinvestigated waterwork Sous in the Jizera Mountains during the last five years was found a permanent overexceed of some limits given by the Drinking Water Standard: pH-value (limit of 6.5-8.5), contents of aluminium (0.2 mg/l), manganese (0.1 mg/l), humin acid (2.5 mg/l) and sum of calcium and magnesium (underexceeded limit because of a 'leached off' soils of upper planes).

DISCUSSION AND CONCLUSION

Hydrologic characteristics influence directly the volume of invested capital into water reservoirs and technical activities on streamwater or ground aquifers. In past a negative socio-economic influence on operational hydrology in our country was discussed. The projects of one milliard invested capital included usual only several thousands Czechoslovak crowns in investigation on hydrology. Hydrologic characteristics have been estimated by statistic of short runoff data series often measured in unstable profiles with an evident change of rating curves. The air pollution damage effects on environment provoked here greater interest in hydrology and forest hydrology during the past ten years. It was found that the up to date technical hydrology on streamgage network is not able to solve the new problems of dynamic changes of parameters in basin. Therefore it was necessary to take into account several different methods. The forest hydrology on small basin approach contributed to the knowledge of runoff genesis and the relation between water quantity and quality. The described changes of water yield correspond with the data of Bosch and Hewlett's (1982) overview, considering mean annual precipitation here. The investigation of archival data seems to be very helpful in the flood regime study, as well as the remote sensing to register fast dynamics of forest and soil changes. The observed rapid growth of herbaceous vegetation with the spruce cover decline mitigated the effect of 'deforestation'. The longterm acid deposition on upper planes of the Jizera Mountains is the reason of described 'leached off' soils with absence of calcium and magnesium and extreme contents of aluminium in streamflow. The regime of water quality in adjacent drink water reservoirs makes it impossible to treat this water by waterwork to keep the limits of Drinking Water Standard, this negative influence of population health there is evident.

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COMPARISON OF CATION LEACHING IN FIVE NORTHERN HARDWOOD STANDS ALONG AN AIR POLLUTION GRADIENT USING A THROUGHFALL MODELING APPROACH

Hal O. Liechty, D. D. Reed, G. D. Mroz, and M. F. Jurgensen

Research Scientist, Associate Professors, and Professor
School of Wood Products and Forestry

Michigan Technological University
Houghton, Michigan

FDC: 116.1: 181.3: 425.3

SUMMARY

Five northern hardwood sites were established along a wet sulfate deposition gradient in the Great Lakes Region of the United States. Stand and soil characteristics of the sites were similar. Precipitation and throughfall was collected weekly at each site during the growing season of 1988. Canopy exchange rates of Ca^{2+}, K^{+}, and Mg^{2+} were determined for each site by fitting a net deposition model to the precipitation and throughfall chemical fluxes measured during the study period. An approximate two and eight fold increase along the gradient in volume weighted precipitation concentrations of SO_4^{2-} and H^{+} respectively were evident during the study period. Foliar leaching of K^{+} and Ca^{2+} was positively related to concentrations of H^{+} in precipitation. No significant differences in canopy exchange rates of Mg^{2+} were found among the sites. Canopy exchange rates of K^{+} appeared to be more sensitive to changes in precipitation acidity than were Ca^{2+} exchange rates.

Keywords: Canopy exchange, precipitation acidity

INTRODUCTION

Forest ecosystem nutrient cycles are intrinsically related to the quality and quantity of atmospheric deposition on forest canopies. Alteration of the chemical composition of atmospheric deposition may have a profound effect on the rates of nutrient cycling of forest ecosystems. Increases in anthropogenic sources of SO_4^{2-} and NO_3^{-} have altered the atmospheric loading and deposition of these anions as well as acidic species of these anions to forests. One of the postulated effects of the increased acidic deposition on

nutrient cycles has been the increased leaching of base cations (Ca^{2+}, Mg^{2+}, and K^{+}) from forest canopies due to the increased levels of H^{+} and the replacement of base cations by H^{+} on leaf surfaces (Tukey 1980, Tamm and Cowling 1977). Studies designed to evaluate this hypothesis have generally indicated that foliar leaching of Ca^{2+}, Mg^{2+}, and/or K^{+} increases with increasing precipitation acidity (Mitterhuber et al. 1989, Scheir 1987, Scherbatskoy and Klein 1983, Evans et al. 1981, Fairfax and Lepp 1975, Wood and Borman 1975) although other studies (Simmons and Kelly 1989, Haines et al. 1985) have shown no relationship between precipitation acidity and cation leaching. Regardless of the results these studies were conducted under laboratory settings and/or employed simulated precipitation solutions as the acidic treatments. While these studies have made important contributions concerning the relationships between precipitation acidity and canopy exchange of cations, they may not reflect actual foliar leaching rates of cations under field conditions due to their artificial nature.

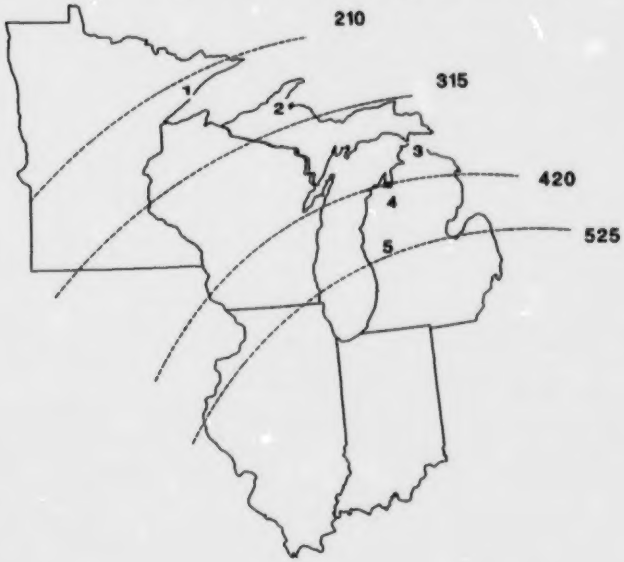
Field experiments, developed to test hypothesis relating canopy exchange of cations to acidic deposition, have generally not been implemented due to the inherent problems of establishment of control and treatment units given regional levels of acidic deposition. This paper reports the results from an regional field study which was developed in part to determine the effect of acidic deposition on canopy leaching of cations. Treatment units in this study were five northern hardwood sites located along a acidic deposition gradient in the Great Lakes Region. Specific placement of the study sites along the gradient were designed to give a series of acidic treatments which correspond to present levels of acidic deposition in the Great Lake Region.

EXPERIMENTAL METHODS

Site Location

The five study sites were established along the Great Lakes Regional pollution gradient in the summer of 1987. The pollution gradient extends from southeastern Michigan where wet deposition of SO_4^{2-} averages approximately 525 eq ha^{-1} yr^{-1} to northeastern Minnesota where wet deposition rates of SO_4^{2-} average approximately 210 eq ha^{-1} yr^{-1} (Figure 1). Deposition of H^{+} averages 500 eq ha^{-1} yr^{-1} and 100 eq ha^{-1} yr^{-1} respectively at these two areas. Study sites were located along the gradient with the intent of implementing a twofold increase of wet SO_4^{2-} and a three to four fold increase in wet H^{+} deposition among the sites.

Figure 1. Location of study sites (1-5) along Great Lakes regional wet sulfate (eq/ha/yr) gradient



The study sites were located near Tofte, Minnesota (1), the towns of Alberta (2), Pellston (3), Wellston (4) in Michigan, and in Oceana County (5), Michigan (Figure 1). The study sites span 4 degrees of latitude and 6 degrees of longitude and are very similar in terms of forest stand characteristics (Table 1). All sites average between 29.5 and 31.8 m^2 ha^{-1} of basal area. Sugar maple (Acer saccharum Marsh.) comprises at least 75% of total stand basal area and biomass at each site. Total stand biomass ranges from 212 to 275 Mg ha^{-1}, with the two sites at the extremes of the gradient (Tofte and Oceana) having the lowest biomass. Stand ages are similar, ranging from 73 to 79 years. All sites have soils developed on morainal landforms which have udic moisture regimes and are moderately well to well drained. Soils at all sites were classified in four closely related subgroups within the Spodosol order.

Chemical fluxes and weighted volume concentrations of SO_4^{2-} and H^+ during the first year of the study are presented in Table 1. Due to the below normal precipitation at southern

Table 1. Locations and selected attributes of the study sites and chemical fluxes and concentrations at the study sites (10/87-10/88)

	Site 1	Site 2	Site 3	Site 4	Site 5
			Site Description		
Latitude (N)	47° 41′	46° 52′	45° 33′	44° 23′	43° 40′
Longitude(W)	90° 44′	88° 53′	84° 51′	85° 50′	86° 09′
Basal Area (m^2 ha^{-1})	31.4	31.8	29.5	30.1	29.9
Sugar Maple Basal Area (%)	89.7	86.3	85.7	82.7	74.8
Biomass (Mg ha^{-1})	212	261	261	275	234
Overstory Age	78	79	73	74	78
		Incident Precipitation Fluxes (eq ha^{-1} yr^{-1})			
SO_4^{2-}	205	233	306	320	314
H^+	74	89	297	277	207
		Volume Weighted Precipitation Concentrations (meq L^{-1})			
SO_4^{2-}	0.028	0.023	0.049	0.042	0.028
H^+	0.009	0.010	0.040	0.035	0.028

sites and the above normal precipitation at the northern sites, the two fold increase in SO_4^{2-} deposition among the sites was not realized. However the volume weighted concentrations of SO_4^{2-} and H^+ were similar to the long term averages of these ions for these areas.

Sampling Methods

At each site three analogous 30x30 meter plots were established with a 10 meter buffer zone (Reed et al. 1990). Five throughfall collectors were located within each plot at each site. These collector locations were fixed for the duration of the study. The collectors consisted of a four liter bottle fitted with a 16 cm diameter funnel. The funnels were covered with a a 3 mm mesh polyethylene screen to eliminate large organic debris. Field samples were collected and their volumes recorded weekly. After collection samples were composited on a plot basis prior to chemical analysis.

Incident precipitation chemistry and amounts were monitored on a weekly basis at collection stations located within 15 km of each research site. Where study sites were located with 15 km of a Class A or B certified National Atmospheric Deposition Program (NADP) precipitation collection site (Site 3 and Site 4), precipitation amounts and chemical concentrations were obtained from the NADP. At the remaining sites Aerochem Metrics wet/dry collectors and Belfort recording rain gauges were installed and operated per NADP protocols. Throughfall and incident precipitation was collected during the same day and within 1 to 4 hours of each other at each site and during each collection date

Throughfall samples and incident precipitation samples were analyzed for pH within 72 hours after collection. Samples were then passed through a .45 μm filter and then stored at 4 to 5^{o} C in dark bottles until further chemical analysis. Anion concentrations were determined using ion chromatography and cation concentrations were determined by atomic absorption spectrophotometry.

Collection of throughfall and incident precipitation was initiated in the late summer of 1987.

Model Description

Cations in throughfall consists of fluxes from incident precipitation, dry deposition, and canopy exchange. Since dry deposition is not monitored at the sites, canopy exchange could not be determined by means of a simple budget method. Instead a modeling approach similar to that of Lovett and Lindberg (1984) was used to determine canopy exchange at each site. The underlying rationale for the model is represented by the following equation attributable to Lakhani and Miller (1980) and Bache (1974).

$$T=B-I=D+C$$

Where: T=Net deposition in throughfall
B=Sum of deposition in throughfall via incident precipitation, dry deposition, and canopy exchange
I=Deposition from incident precipitation
D=Dry deposition
C=Canopy exchange

Lovett and Lindberg (1984) indicated that for a given rainfall event that completely washes the canopy, the previous equation can be written as follows.

$$T=D+C=b_1A+b_2P$$

Where: A=Antecedent time between events
P=Amount of precipitation during an event

The b_1 coefficient represents a mean dry deposition rate associated with the interval between events. The b_2 coefficient represents a mean exchange rate associated with the amount of precipitation. Since canopy exchange takes place only in the water processed through the canopy, in this study the amount of throughfall was substituted for the precipitation amount variable.

Preferably this equation would be fitted to individual rainfall/throughfall events. However, the costs associated such an intensive study over a large region and long time frame are prohibitive. Thus the model was fitted to each weekly collection of throughfall and precipitation from the sites. The use of weekly collection intervals instead of event data necessitated that components of the model be modified with respect to the weekly information. For example the antecedent time interval variable for a given collection week was defined as the sum of two measurements: 1) the nonevent hours prior to the last event during the collection week which completely washed the canopy and 2) the nonevent hours after the last event which washed the canopy from the previous collection week. This definition assures that periods of dry deposition loading to the canopy which were not washed from the canopy are associated with the proper week of throughfall collection. Nonevent hours were determined from the precipitation event and amount recording charts of the weighing rain gauges at each site.

The amount of precipitation required to wash the canopy was assumed to be the amount of precipitation required to produce a measurable amount of throughfall. This amount was determined by regression equations fitted to throughfall and incident precipitation amounts. The regression equations indicated that this amount was between 0.10 and 0.20 cm of precipitation at each site. In order to make calculations uniform at each site, 0.15 cm was assumed to be the amount of precipitation needed to wash the canopy.

Use of weekly measurements in the model also required adjustments of the measured deposition of materials deposited by rain events which did not wash the canopy during a given week but were washed into samples collected in subsequent weeks. Deposition from events of less than or equal to 0.15 cm which occured after the last event of greater 0.15 cm in a given week were subtracted from the total deposition amount of that week and added to the amount of deposition in the following week. Deposition from these events were calculated by multiplying the event amount by the concentration of the cation in precipitation for the week in which they occured.

Obviously there are a number of stand characteristics which could introduce variation to the model or bias estimates of the coefficients in the model. One stand characteristic which will greatly influence the model is the amount of leaf area that precipitation travels through before it reaches the ground. Variability in leaf area within sites or among sites could possibly confound the effects of precipitation chemistry on canopy exchange rates and dry deposition rates. Leaf area index was determined for each plot in the summer of 1988. Net deposition (eq m^{-2}) for each site, plot, and week of collection after leaf expansion and prior to leaf fall was divided by leaf area index (m^2 m^{-2}) to minimize potential confounding effects of leaf area on coefficient determination. The resulting quotient gave net deposition in terms of equivalents of cation per unit of leaf area.

The following equation shows the final form of the model which was fitted to the data set by least squares regression.

$$D_{(eq\ m^{-2})} = b_o + b_1 \times A(hr) + b_2 \times P(cm)$$

Where: b_o=meq m^{-2}(leaf area)
b_1=meq m^{-2}(leaf area) hr^{-1}(nonevent)
b_2=meq m^{-2}(leaf area) cm^{-1}(throughfall)

Although the intercept should theoretically be equal to 0, it was retained in the equation. The addition of the intercept term allowed for possible adjustments to the model for canopy particulates which fall in the throughfall collectors not explained by the dry deposition rates or evaporation of throughfall samples in the collectors.

The model was separately fitted to net throughfall deposition at each site. Plots were considered as replicate observations for a given week and site. Due to possible dry deposition of cations in bulk throughfall collectors during the dormant season, the model was only fitted to weekly net deposition during the 1988 growing season (Richter and Lindberg 1988). Weeks without precipitation events, events which did not provide sufficient quantities of precipitation for chemical analysis, or periods when equipment failure did not allow variable measurement were excluded from the analysis. Given these limitations the data set used for fitting the model contained between 10 and 16 weeks of samples for each site.

RESULTS

The fitted equations for each cation and site are presented in Table 2. Coefficients associated with canopy exchange and dry deposition were significant (p=.05) for all sites and cations with the exception of site 1. Model

Table 2. Intercept (b_0), canopy exchange rate (b_1), dry deposition rate (b_2), coefficient of determination (r^2), standard error, and number of observations for net deposition equation for each site and cation.

	b_0 ($meq\ m^{-2}$)	b_1 ($meq\ m^{-2}cm^{-1}$)	b_2 ($\mu eq\ m^{-2}hr^{-1}$)	r^2	Standard Error	N
Site 1						
Ca^{2+}	.101	.007	-.122	.076	.051	29
K^+	.235	.023	-.271	.054	.176	29
Mg^{2+}	.083	-.003	-.120	.025	.049	29
Site 2						
Ca^{2+}	.013	.032 b[1]	.166 b	.601	.043	32
K^+	-.003	.027 c	.240 a	.465	.054	32
Mg^{2+}	-.003	.008 a	.136 c	.513	.019	31
Site 3						
Ca^{2+}	.056	.022 b	.100 b	.564	.036	44
K^+	-.062	.047 b	.538 a	.773	.062	44
Mg^{2+}	-.003	.008 a	.161 b	.769	.015	44
Site 4						
Ca^{2+}	-.029	.061 a	.411 a	.451	.053	48
K^+	-.134	.124 a	.820 a	.599	.080	48
Mg^{2+}	-.010	.016 a	.239 a	.282	.031	48
Site 5						
Ca^{2+}	-.173	.037 b	.508 a	.542	.068	40
K^+	-.134	.019 c	.297 a	.451	.045	40
Mg^{2+}	-.008	.006 a	.301 a	.401	.039	40

[1]Canopy exchange or dry deposition rates for a given cation with the same letter not significantly different (p=.05)

performance for this site was extremely poor. The performance of the model at this site appeared to be related to insect defoliation at the site during the study period. Defoliation began in early summer and by the end of July the canopy was approximately 30% defoliated.

Defoliation can affect canopy exchange and dry deposition rates in a number of ways. Removal of the canopy decreases the amount of foliar surface area available for exchange of ions in precipitation and removal from the air. A number of more mobile ions such as K^+ can be leached more readily after foliar injury. Furthermore mineral deposits from frass and leaf

particles are either washed or directly deposited in the throughfall collectors. Introduction of these contaminants can greatly add to the variation associated with the model. Evidently inputs from canopy exchange and dry deposition were confounded to such a degree with the effects of the insect defoliation that determination of the coefficients in the model were impossible. Thus results from this site were eliminated from any further analysis involving canopy exchange rates and acidic deposition.

Coefficients of determination (r^2)for the sites and cations with the exception of Mg^{2+} at site 4 were between .40 and .77. Intercepts terms were not significantly different from 0 (p=0.05) except for K^+ and Mg^{2+} at site 3 and K^+ at site 4. No specific explanation from this study could be made as to why these intercepts were significant while intercepts from other sites or cations were not significant.

Positive canopy exchange rates in Table 2 indicate foliar leaching of all cations at all sites. Although differences among canopy exchange rates among sites were not always significant, exchange rates generally increased from Site 2 to Site 4 but decrease again at Site 5. With the exception of site 5 which had dry deposition rates of Ca^{2+} and Mg^{2+} greater than Site 4, dry deposition rates for each site followed similar trends to those of canopy exchange

Canopy exchange rates of Ca^{2+} and K^+ were significantly greater (p=.05) at Site 4 than at the other three sites. Average volume weighted concentrations of H^+ and $SO_4{}^{2-}$ from the precipitation samples used for model development were also highest at Site 4 (Table 3). Foliar leaching rates of K^+ significantly increased along the gradient from Site 2 to Site 4. Changes in foliar leaching of K^+ among these three sites were positively correlated to increases in precipitation concentration of H^+ and $SO_4{}^{2-}$ (Table 3). An eight fold

Table 3. Incident precipitation concentration (meq L^{-1}) and canopy exchange rates (meq m^{-2} cm^{-1}) for each site

	Precipitation Concentration		Canopy Exchange Rate		
	H^+	$SO_4{}^{2-}$	Ca^{2+}	K^+	Mg^{2+}
Site 2	.005	.025	.032	.027	.008
Site 3	.034	.041	.022	.047	.008
Site 4	.045	.050	.061	.124	.016
Site 5	.032	.044	.037	.019	.006

increase in H^+ concentration in precipitation corresponded to a four to five fold increase in K^+ canopy exchange among these three sites. Increase foliar leaching of K^+ with increasing precipitation H^+ concentrations suggest displacement of K^+ by H^+ in the canopy.

Foliar leaching of K^+ at Site 5 was much lower than was expected given the apparent relationships between precipitation H^+ and foliar leaching at the other three sites. The depressed leaching rate of K^+ at this site appears to be related to low foliar K^+ concentrations at this site. Average midsummer foliar concentrations of K at the other three sites were between 0.80 and 0.85% while foliar concentrations at Site 5 averaged 0.68%. The lower levels of foliar K evidently indicate a lower level of K^+ available for exchange by precipitation passing through the canopy.

Although foliar leaching of K^+ increased with precipitation acidity, the relationship between K^+ leaching and H^+ concentrations was not linear (Table 3). A 0.029 meq L^{-1} increase in H^+ precipitation concentration between Site 2 and Site 3 corresponded to a 0.020 meq m^{-2} cm^{-1} increase in K^+ leaching. However differences in H^+ concentrations and foliar leaching of K^+ between Site 3 and Site 4 were 0.009 meq L^{-1} and 0.077 meq m^{-2} cm^{-1} respectively. The nonlinear relationship between foliar leaching and precipitation concentration could be a result of different dry deposition rates of H^+ at the sites. Increased dry deposition of H^+ in relation to wet deposition of H^+ at Site 3 or 4 compared to Site 2 would enhance leaching of K^+ and confound any linear relationship between H^+ in precipitation and K^+ leaching.

Foliar leaching of Ca^{2+} was also significantly greater at Site 4 than the other three sites. It does not appear that foliar leaching of Ca^{2+} was as sensitive to increases of precipitation acidity as was foliar leaching of K^+. Increases in leaching rates of Ca^{2+} from foliage of Acer rubrum (L.) have been reported for a artificial precipitation pH of 3.2 (Schier 1987). Significant differences in canopy exchange rates from our study were evident at a pH of 4.3.

CONCLUSIONS

Foliar leaching of K^+ and Ca^+ was enhanced while foliar leaching of Mg^{+2} was unchanged by increased levels of H^+ in precipitation. Canopy exchange of K^+ was increased to a greater degree than was Ca^{2+}. An increase in precipitation H^+ concentration of 0.040 meq L^{-1} corresponded to increases in foliar leaching of 0.029 meq of Ca^{2+} and 0.097 meq of K^+ per centimeter of throughfall.

Relationships between foliar leaching of these cations and precipitation acidity were not linear. Deviations in a linear relationship between foliar leaching and precipitation concentrations of H^+ may be a result of change wet to dry deposition rates of H^+ along the gradient.

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THE WATER AND SOIL CONSERVATION FUNCTIONS AND HYDROLOGICAL INFLUENCES OF BLACK LOCUST PLANTATION

Wang Yanhui

The Institute of Forestry
The Chinese Academy of Forestry, Beijing, China

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SUMMARY

Black locust (Robinia pseudoacacia Linn.) has become one of the important shelter species in the soil erosion region in the Northwestern China. In this paper, the research results which were obtained in recent years were summarized, including canopy interception, variation of rainfall kinetic energy, litter absorbability, effect of root system on wash resistence and soil stability, increasement of infiltration rate and decreasement of water and soil losses, forest transpiration and soil water variation etc.. Some data and models were also reviewed. Finally, based on all the obtained research results, the structural indexes of well benefited plantation were suggested, and the problems which should be given more attentions in the future researches were pointed out.

Keywords: Black locust, Forest hydrology, Water and soil conservation, Plantation

INTRODUCTION

Black locust was introduced from Germany in the begining of the 20th century. It has already become one of the important species of shelter forest in the northwestern soil loss region. With area's increasing, the rule on maintaining ecological balance and preventing soil and water losses has been getting more and more important. In recent years, Chinese Scientists have done some researches about black locust plantation. In order to make the future researches more systematic and more detailed and give a better guideline to forestry activities, the obtained research results were summarized in this paper.

RESEARCH RESULTS

Canopy Interception

It is the canopy interception that causes the decreasement of ground-reached rainfall, stemflow, the variation of rainfall KE (kinetic energy). The research by Liu Bingzheng et al. (1989) showed that there was a big difference of interception among different tests, because the effects of canopy properties and rainfall characteristics varied according to different conditions . But in the case of averaged rainfall and general plantation with ages older than 8 years, the intercepted amounts were 2.5 mm for rainfall less than 10 mm, 3.5 mm for 10-30 mm, and more than 3.5 mm for more than 30 mm, respectively, with a maximum of 7 mm interception. For a plantation with canopy density of 0.3-0.5, 0.5-0.8, >0.8, the corresponding interception rates of annual rainfall were 8.36%, 10.67%, 15.96%, respectively.

Giving a proper consideration to the physical mechanism and making some simplifications, Wang Yanhui (1986) derived a parameter model in which the effects of canopy and rainfall on interception were presented. The parameter values were also determined by fitting measured data from 7-12 year old trees:

$$\begin{cases} I_c = I_{cm}^*\left(1-\exp\left(-\dfrac{P \cdot C_d}{I_{cm}^*}\right)\right)+0.051T \\ I_{cm}^* = 1.48C_d^{0.13}\Delta H^{0.13}\Delta T^{0.09} \end{cases} \qquad (1)$$

Where, I_c-the averaged depth of interception over the canopy projective area for a single tree (mm); I_{cm}^*-the absorbability of leaves and twigs (mm); P-rainfall amount (mm); C_d-canopy density (decimal); T-rainfall duration (h); ΔH-canopy thickness (m); ΔT-time interval from the begining of counted rainfall event to the end of last rainfall event (day).

The research showed that the quantity of stemflow was mainly dependent on the rainfall amount. The stemflow model was derived from measured data as follows:

$$S_f = 0.027P^{1.185} \qquad (2)$$

Where, S_f-the averaged depth of stemflow over the canopy projective area for a single tree (mm).

It will not be difficult to use the two equations above to calculate interception and stemflow under any conditions.

Other interception models are often over-simple linear regression equations, so it is unnecessary to go into details.

Rainfall KE Caused by Canopy

Rainfall KE is an important factor and energy resource which leads to soil structure destruction, infiltration rate decline, and soil erosion. By changing part of rainfall into canopy inter-

ception and slow stemflow, and by changing the size distribution and falling height of raindrop , the rainfall KE per unit volume changes.

The research by Wang Yanhui (1986) showed that the raindrop size distribution of canopy rainfall, which was composed of canopy drips and canopy splashes, was obviously unaffected by the intensity and type of rainfall in opens. Using Best (1950) equation to regress measured data, the size distribution of canopy raindrop of black locust was determined as follows:

$$F=1-\exp(-(\frac{D}{2.5112})^{2.6126}) \qquad (3)$$

Where, F-the percentage of accumulated volume of raindrops to which diameters are equal or smaller than D; D-raindrop diameter (mm).

Because the ground-reached velocity of a raindrop will be much different when it falls from different heights, it is necessary to list the canopy rainfall KE per unit volume with its falling heights (Table 1).

Table 1: KE per unit volume of canopy rainfall of black locust

H (m)	E_{dh} ($J/m^2/mm$)	H (m)	E_{dh} ($J/m^2/mm$)	H (m)	E_{dh} ($J/m^2/mm$)	H (m)	E_{dh} ($J/m^2/mm$)
0.01	0.098	2.60	14.606	5.60	20.392	13.00	23.427
0.05	0.482	2.80	15.214	5.80	20.603	14.00	23.514
0.10	0.948	3.00	15.779	6.00	20.801	15.00	23.579
0.20	1.842	3.20	16.304	6.20	20.985	16.00	23.627
0.40	3.492	3.40	16.793	6.40	21.158	17.00	23.663
0.60	4.987	3.60	17.247	6.60	21.319	18.00	23.689
0.80	6.349	3.80	17.669	6.80	21.470	19.00	23.709
1.00	7.595	4.00	18.063	7.00	21.612	20.00	23.723
1.20	8.739	4.20	18.430	7.50	21.926	21.00	23.734
1.40	9.790	4.40	18.771	8.00	22.195	22.00	23.742
1.60	10.758	4.60	19.090	8.50	22.422	23.00	23.748
1.80	11.652	4.80	19.388	9.00	22.616	24.00	23.753
2.00	12.478	5.00	19.665	10.00	22.922	26.00	23.758
2.20	13.242	5.20	19.924	11.00	23.144	28.00	23.763
2.40	13.950	5.40	20.166	12.00	23.307	30.00	23.765

Whether the rainfall KE can be reduced by canopy, on the one hand, depends on the proportions of energy-lost interception and stemflow to the total rainfall, on the other hand, depends on the rainfall characteristics, because the KE per unit volume varies with rainfall intensity and type. If we only compare the KE per unit volume between canopy rainfall (not floor-reached rainfall) and the rainfall in opens, the relative portion varies with falling height (the canopy centre height) and rainfall type (frontal

or convective). If the falling height and rainfall type are fixed , the KE per unit volume of rainfall with intensity bigger than a critical intensity will be decreased in the case that the rainfall is entirely transformed into canopy rainfall and vice versa.

In this study, a case event of raindrop KE decreasement of a rainstorm in a 8-year old plantation was simulated. the result showed that, in the natural ranges of variation, if the canopy density was raised from 0.4 to 1.0, the percentage of KE decreasement would be raised from 24% to 48%. If the canopy centre height was lowered from 9 m to 3 m, the decreasement would be raised from 35% to 45%. Only in the range of lower than 3 m, the lowering of canopy centre height could lead to a sharp decreasement of KE. For example, if the height was 0.5 m, the percentage would be raised to 64%. According to this, when the ground cover can not be well maintained, the forestry activities which are used to form a low and dense canopy are effective measures to prevent soil and water losses, such as fuel forest and those mixed with shrubs. In this research, the critical canopy centre heights, which were proposed to reduce soil erosion to a certain degree (Wang Wanzhong, 1984), were roughly estimated (Table.2).

Table 2: The characteristics of each erosion degree

Erosion degree and its quantitative index (t/km^2)	Weak 100-500	Light 501-1000	Middle 1001-5000	Heavy >5000
Intensity when rainfall duration is 60min. (mm/min.)	0.112	0.167	0.243	0.439
Raindrop KE ($J/m^2/mm$)	17.873	20.106	22.456	26.731
Critical canopy centre height (m)	3.9	5.3	8.5	——

The Effects of Ground Cover

The ground cover of black locust plantation is mainly composed of litter, with a little herb. The main effects of ground cover are to protect soil surface from raindrop impact, prevent soil particles from dispersal and prevent pores from sealing, so that surface crust will not form. In addition, ground cover can also absorb rainfall and intercept eroded soil, and contribute itself to the improvement of physical and chemical soil properties by decomposition.

Liu Bingsheng et al. (1987) determined the relation between litter amount and stand averaged breast-height diameter:

$$L=295.0+103.1\ D_{1.3} \quad (4)$$

Where, L-air dry weight of litter (g/m^2); $D_{1.3}$-stand averaged breast-height diameter (cm).

Because the rate of decomposition, retaining abilities and growth statuses are often different from one stand to another, a big difference of litter amount exists among different tests. In general, the retained litter amount is 0.3-0.97 kg/m^2 (Liu Bingzheng et al. 1987).

Under natural conditions, the saturated absorbability of litter can reach 2.93-3.76 times of its air dry weight (Liu Bingzheng et al. 1987). But one laboratory measured value is only 1.73 (Wang Yanhui, 1986). Maybe the reason for the disagreement is the differences of decomposing degree or test method. The litter absorbability declines as ground slope increasing. On the slopes of 30°, 25°, 20°, 15°, the relative absorbabilities are 1, 1.05, 1.15, 1.28, respectively. It was estimated that the water retention ability of litter was 232.6 -500.1 m^3/ha, reaching 8% of rainfall (Liu Bingzheng et al, 1987).

Limited by falling height, sometimes the canopy rainfall can not reduce rainfall KE efficiently. In this case, the sufficient ground cover becomes a necessary guarantee to prevent floor from erosion. According to the simulation analysis by Wang Yanhui (1986), only when the percentage of ground cover reaches more than 50%, can it be ensured that the soil erosion larger than weak degree (100-500 t/km^2) will not happen under heavier storms.

The simulation by Zhou Hongqi (1982,unpublished) showed that the velocity of surface runoff was decreased by 79% by litter.

Soil Stabilization Effect of Root System

The root system of black locust distributes uniformly and shallowly, concentrated mainly within the layer of 5-50 cm, so it plays an important rule on preventing gully erosion and soil slide.

One investigation (Liu Bingzheng et al. 1987) in 4-20 year old black locust plantations showed that the root (≤5 mm in diameter) content in the layer of 0-50 cm reached 48.86-153.23 g/m^2 with an average of 1162 kg/ha. The relation among root content and averaged breast-height diameter and stand height was given as follows:

$$R_5 = 31.219 - 16.151 \lg D_{1.3} + 174.421 \lg h \qquad (5)$$

Where, R_5-root content (g/m^2); $D_{1.3}$-averaged breast height diameter (cm); h-averaged stand height (m).

Using a special device, Liu Bingzheng et al. (1984) measured the soil wash resistence in black locust plantations, with an index of wash modulus, M, the amount of washed soil by unit volume of water. It was found that the wash resistance in the plantation was better than those on grassland and farmland, and the elder the plantation, the better the wash resistance. The main factor affecting wash resistence was the content of fine

root (≤2mm in diameter). The relation between wash modulus and fine root content was given as follows:

$$M=0.552+0.24\frac{1}{R_2} \qquad (6)$$

Where, M-wash modulus (g/l); R_2-fine root content (g/100 cm^3).

Based on the relation between fine root content and breast-height diameter, it was derived that the wash resistence would be significantly raised if the diameter reached 4 cm, i.e. a fine root content of 0.06 g/100 cm^3 (in general, 8 year old plantation). Henceforth, the more increasement of fine root content would not lead to a further significant decreasement of wash modulus.

The reinforcement effect of root system was measured by Yang Weixi et al. (1988) using a method called pulling single root out. The relation between reinforcement of a single root and its diameter was given as follows:

$$F_r=240.06D_r^{1.7821} \qquad (0.15cm\leq D_r\leq 1.96cm) \qquad (7)$$

Where, F_r-the reinforcement of single root (kg); D_r-root diameter (cm).

By calculating the reinforcements in different depthes for different aged stands (Table 3), it was found that the reinforcement of black locust was 3 times of that of Chinese pine (Pinus tabulaeformis Carr.), and increased with the plantation age, but the increasing rate would slow down after the age of 15 years.

Table 3: The root reinforcements in different depthes for different aged plantations

Age (year)	20 cm	40 cm	60 cm	80 cm	100 cm	Stand density (trees/ha)
11	38.55	21.43	12.93	8.93	3.52	6,000
15	52.30	31.95	19.52	17.05	12.79	5,500
20	61.16	34.93	20.26	17.79	13.02	4,400

Increasing Infiltration Rate and Decreasing Water and Soil Losses

Because the content of soil organic matter and ground cover are increased and the effect of hole-boring of root system is supplied, the physical properties on forestland will be improved, i.e. the content of water-stable aggregate and soil porosity will be increased and the hardness will be decreased, therefore, the infiltration capacity can get higher and surface runoff can get lesser. Besides the runoff decreasement, the effects of soil interception and soil protection supplied by ground cover will

lead to a great decreasement of soil loss.

Liu Bingzheng et al. (1987) measured infiltration curves on different aged forestland, farmland and grassland, with double-ring infiltrometer. The measured data were analysed in the form of equation (8). The derived parameters are listed in Table 4.

$$f=a+\frac{b}{t^c} \quad (8)$$

Where, f-infiltration rate (mm/min.); t-infiltration period (min.); a, b, c-parameters

Table 4: The parameters in infiltration model for different land types

Land types	Black locust forest 16 year	11 year	4 year	Natural grassland	Farmland
a	0.88	0.71	0.68	0.61	0.52
b	6.014	2.964	7.390	5.591	1.519
c	0.809	0.766	0.782	0.896	0.767

From Table 4, we know that both the initial and final infiltration rates on forestland are higher than those on grassland and farmland.

Wang Baitian et al. (1988) measured the infiltration rates on forestland with ages from 6 to 12 years, using double-ring infiltrometer, too. They found that it was better to use Philip equation than use others.

$$f=\frac{1}{2}St^{-0.5}+A \quad (9)$$

The parameter A is mainly affected by gravity, while the parameter S is mainly affected by soil porosity D_g(%) and unit weight r(g/cm^3) and water content v(g/cm^3) in surface layer. The relation was given as follows:

$$S=0.549D_g-1.79e^r+2.798v^{-0.5} \quad (10)$$

Based on the given values of S and A of each tested point when v was 0.25, the averages of S and A of 11 forest points located at the lower part of slopes were 4.7212 and 0.2935 and the averages of 10 forest points located at the upper part of slopes were 4.6622 and 0.6658, while the contrastive values on farmland located at upper part of a slope were 3.1008 and o.1220. So it was concluded that the effect on increasing infiltration capacity by black locust plantation was obvious.

By analysing the parameters of infiltration on forestland, it was pointed out that the improvement of infiltration capacity by 6-7 year old plantation was not obvious. Only those with ages of more than 10 years could lead to obvious improvement.

Wang Yanhui (1986) analysed the data of soil and water losses collected in 2 years from 15 different vegetationed plots (black locust plantation, natural grassland, bareland) using step-wise regression method. All the possible affecting factors, such as rainfall, topography, vegetation and soil were considered. The regression equation of surface runoff was given as follows:

$$R_o=P_c(0.1530-0.2041C+0.0005551(1-P_r)E_bI_{10}) \qquad (11)$$

Where, R_o-surface runoff (mm); P_c-effective rainfall (mm), the rainfall in opens minus canopy interception and ground cover absorption; C-ratio of ground cover (decimal); P_r-ratio of level soil preparation (level terrace, level pitting) (decimal); E_bI_{10}-floor reached rainfall erosivity ($J/m^2 \cdot mm/min.$), E_b-floor reached rainfall KE, I_{10}-maximum continuous rainfall intensity of 10 minutes.

The corresponding soil loss regression equation was derived as follows:

$$S_e=0.8937e^{-3.2940C}(E_bI_{10})^{0.5518}E_p^{0.6483(1-P_r)} \qquad (12)$$

Where, S_e-soil loss quantity (g/m^2); E_p-averaged potential energy of runoff per one m^2 in runoff plot (J/m^2).

By analysing the simulation results derived from the above equation (11) and equation (12), it was concluded that the determinant factor to decrease the soil loss and surface runoff was the ground cover ratio. Other affecting factors, in order of importance, were soil preparation ratio, canopy density, canopy centre height. The effect of canopy thickness was small. So, wherever the ground cover can not be well maintained, it should be energetically encouraged that trees be planted with previous soil preparation or/and mixed with shrubs or/and shrubby managed as fuel forest, so that a low and dense canopy can be formed.

Some other researches (Hou Xilu, 1985; Liu Bingzheng et al. 1989) showed that the black locust plantation of about 8 years could reduce runoff by 86-93% and soil loss by 95-99%.

Plantation Transpiration and Soil Water Variation

Zhou Niangen et al. (1983) researched the transpiration rate of 12 year old black locust plantation using fast-weighing method, including diel and seasonal variations. The analysis of diel periodic variation showed that black locust transpirated day and night with a single-peak curve of transpiration rate. The peak appeared at 12 o'clock and the higher rate period appeared from 10 to 16 o'clock and the lower rate period appeared from 0 to 4 o'clock. According to the converted results from the originals, the maximum rate was 0.42 mm/h. The seasonal pattern of daily transpiration of black locust plantation is illustrated in Table 6.

Table 6: Seasonal pattern of daily transpiration of black locust plantation

Month	June		July			August			September	
Ten days	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
Daily trans. (mm/day)	3.93	4.41	3.48	3.54	3.55	4.23	2.35	2.25	2.04	1.87

According to Table 6, the seasonal pattern is a double-peak curve, one appears at the 3rd ten days of June and another at the 1st ten days of August. The period from the 2nd ten days of June to the 1st ten days of August is higher rate period. Based on the data in Table 6, it can be derived that where the annual precipitation is more than 500-600 mm, the water is enough to meet the need of tree growth.

Wang Yanhui (1989) researched the soil water declination on black locust plantation with ages from 8 to 12 years during a period from August to September in 1984. The evaluating index was the parameter of soil water declination, K, in the equation (13).

$$W=(W_o-W_{min})K^t+W_{min} \qquad (13)$$

Where, W-water depth contained in one soil layer (mm); W_o-initial water depth contained (mm); W_{min}-the minimum water depth contained (mm); t-declining duration (day).

The averages of K of different vegetation types at different locations on a slope in different soil layers, 0-5 cm, 5-10 cm, 10-20 cm, 20-40 cm were calculated (able 7).

Table 7: The variation of K with vegetation types and locations

Vegetation types	Location on a slope	K_{0-5}	K_{5-10}	K_{10-20}	K_{20-40}	Number of tested points
Bareland	Upper part	0.7940	0.9500	0.9773	0.9943	3
Grassland	Upper part	0.8201	0.8987	0.9500	0.9759	2
	Lower part	0.9022	0.9256	0.9560	0.9656	2
	Average	0.8611	0.9121	0.9530	0.9707	
Forestland	Upper part	0.8285	0.8814	0.9232	0.9933	3
	Lower part	0.9184	0.9455	0.9602	0.9865	5
	Average	0.8847	0.9215	0.9463	0.9891	

From Table 7 we know that the effect on soil water declination by location on a slope is the biggest one. The difference of

K caused by location is often larger than that caused by vegetation types. The difference of K between forestland and natural grassland is small, and the patterns of variation of K with the increasement of depth are also similar. The feature of K at vegetation covered sites is that K gets relative larger at surface layer and relative smaller at deeper layer, i.e., a gentle slope of variation, while the feature of K at bare site is on the contrary.

In this paper, the predicting equations of K for different layer were also derived by step-wise regression. These equations showed that K at surface layer was mainly affected by topography, while the effect by vegetation was small. In a certain range, with the increasing of depth, root content got larger and the effect of vegetation got stronger.

CONCLUSIONS

The results we have got about the shelting effects of black locust plantation can be briefly summarized as follows:

1. In general, the intercepted amount can reach 8-16% of annual rainfall. A more detailed interception model was derived. Stemflow models were also established.

2. The raindrop size distribution of canopy rainfall was determined and the raindrop KE per unit volume with different falling heights was calculated.

3. The saturated absorbability of ground cover in natural status can reach 2.93-3.76 times of its air-dry weight. The absorbed amount can reach 8% of annual rainfall.

4. The main factor affecting wash resistence of forestland is the content of fine root with diameter thinner than 2 mm. The equation of single root reinforcement was derived and the reinforcement of different aged forestland was also calculated.

5. The runoff and eroded soil from forestland can be reduced by 86-93% and 95-99% respectively, compared with those from farmland. Several infiltration models were determined. The surface runoff equation and soil loss equation in which the main affecting factors were considered were also established.

6. The daily transpiration amount has an obvious seasonal variation, in a range of 1.87-4.23 mm/day; The transpiration rate has an obvious diel periodical variation, in a range of 0-0.42 mm/h. On the whole, black locust transpirates day and night. The abilities of water consumption of forestland and natural grassland are close to each other.

The main problems we must pay much attention to in the future are as follows:

1. The systematization and physical mechanism.

2. The blank and weak links needed to worked on, such as water quality, water budget, watershed hydrological effect, evapotranspiration and soil water variation, rational treatments and indexes of forest management.

3. Researches on mature plantations and on mature forestlands in order to get a better and complete evaluation.

The characteristics of an excellent shelter forest of black locust should be:

1. A higher ratio of ground cover. It should be maintained more than 50%. During the period of young forest, the low ratio of ground cover can be increased by reserving or cultivating living ground cover or be compensated by soil preparation.

2. A low and dense canopy. The canopy should be completely or nearly closed. When no or only a little soil protection is supplied by ground cover, the canopy centre height should be less than 5.3 m, or even less than 3.9 m if it is managed as fuelwood.

3. An enough age. With an age more than 8 years, the wash resistence can be obviously increased; With an age more than 10 years, the infiltration capacity can be obviously raised; With an age more than 15 years, the root reinforcement of forestland can reach the maximum.

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TEN YEARS RESEARCH IN EROSION CONTROL BY FOREST AND GRASS COVER IN SMALL EXPERIMENTAL MOUNTAIN WATERSHEDS

Miroljub Djorović and Grigorije Macan

Professor and Associate Professor

Forestry Faculty, Belgrade University
Belgrade, Yugoslavia

FDC: 116.64: 233: 116.2: (23)

SUMMARY

Soil erosion in hilly mountain regions, considering on-site and off-site damages, is very important. In erosion control, grass cover as well as forest cover are studied and applied in practice very often, but there are still many scientific, technical and economical problems to be solved. That is why, two small watersheds of 7.6 ha and 6.4 ha are set up in mountain Goč in republic Srbia as experimental stations for multipurpose research of erosion,run off and in the same time for the study of the effects of forest and grass cover in longterm erosion control. The ten-year results of this research for the period 198o-1989 are presented in this paper.

Keywords: forest cover, grass cover,soil erosion,water discharge

INTRODUCTION

Soil erosion in mountain regions in Yugoslavia, considering total damages, is important factor which limits the use of forest and agriculture lands.

In soil erosion control of these areas, forest cover as well as grass cover are very often applied in practice but, as far as Yugoslavia is concern, with insuficient quantitative data of their efficiency.

Therefore a net work of small experimental watersheds has been set up by Forestry Faculty of Belgrade University in Republic Srbia,designed for multipurpose research of erosion and run off. Experimental watersheds represent hilly-mountain region of Central part of Republic Srbia, covering 55,ooo km².

In these investigations, special attention is directed towards the study of the influence of different vegetative covers on soil erosion and water discharge, and some of the results of ten-year investigation on two small watersheds,one under forest and the other under grass cover,will be presented.

EXPERIMENTAL METHODS

Study of water erosion in order to assess the magnitude and impact of soil erosion belongs to that kind of the problems which could not be ideally solved.The reason is in numerous erosion factors and their combinations that exist in nature. That is why ideal methodology does not exist either, but realistic objectives for erosion studies could be reached by careful selection and combination of existing methods.

Most of erosion studies recognize two basic approaches: watershed studies and field and laboratory plot studies(Lal 1988) Having in mind the basic aim of the research which is the study of erosion control effects of forest and grass covers,we accepted the method of small watershed as the most adequate method for this investigation.

According to this method, two small watersheds R-1 and R-2 with area of 7.6 and 6.4 ha respectively are set up in mountain Goč in western part of Republic Srbia. These two small watersheds are touching each other with very similar characteristics with only one difference and it is:cover. Watershed R-1 is under very dense cover of softwood forest and watershed R-2 is under good grass cover.

Sediment discharge is measured by weighing the total colected material in stilling basin of the weir. Measurments are performed after draining the stilling basin and whole deposition is measured at air-dry level once a month.

The water discharge is measured by compound sharpe crested weir consisting of rectengular and triangular weir (Fig.1). The weir is equipped with water level recorder and nearby this water discharge structures, recording gage and other standard metheorological instruments are set up.

Water discharge and rainfall and other metheorological characteristics are measured by standard procedure regulated by Hydro-Metheorologic Service of Republic Srbia.

RESULTS

Table 1 presents the basic characteristics of two small watersheds R-1 which is under forest cover of soft wood (Pinus nigra 72 % and Picea excelsa 28%) and watershed R-2 which is under good grass cover.

Figure 1: Water discharge control structure at watershed R-1 .

Table 1 : Physical charcteristics of the experimental watersheds R-1 and R-2

Physical caracteristics	Watershed R-1	Watershed R-2
Area (km²)	o.o76	o.o64
Length (km)	o.425	o.25o
Circumference (km)	1.o75	o.875
Elevation (m.above sea level)	88o.o	892.o
Soil	Siliceous soil	
Geological substrata	Serpentinized peridotite	
Cover	Pinus nigra (72%) Picea excelsa(284)	Grass (loo %)

Sediment discharge data collected during investigation period 198o - 1989 are presented in table 2. They indicate that soil erosion is far under erosion tolerance of 2.o tons per ha annually for both watersheds (Djorović 1974).

Table 2 : Sediment discharge in kg. for the period 198o - 1989.

Year	Watersheds R - 1	Watersheds R - 2
198o	64	5o
1981	75	6o
1982	53	38
1983	54	5o
1984	61	57
1985	5o	47
1986	55	43
1987	42	3o
1988	48	26
1989	63	32
Mean annual (kg)	56.5o	43.3o
Mean annual (kg $ha^{-1}year^{-1}$)	7.43	6.76
Mean annual (kg $km^{-2}year^{-1}$)	743.oo	676.56

Water discharge characteristics presented in table 3 and fig. 3,4,5,6,and 7, point out to the certain facts:

- Duration of the flow (T) for an average year is for 28% longer under forest cover, watershed R-1, than in watershed R-2 which is under grass cover,fig. 3;
- The rate of the flow (Q), minimal flow (Qmin.), maximal flow (Qmax.), total water discharge (Pe) and run off coefficient (n) are higher for watershed R-2 (grass cover) than in watershed R-1 (forest cover).

These differences are mainly the result of the nature of forest and forest soil to store a considerable amount of pricipitation water in canopy, in the litter on the forest floor and especially in the soil root zone (Brechtel 1982).At the same time these characteristics are very important factors in flood control and erosion prevention and they compensate reduction of total amount of water discharge, what should be regarded as disadvantage for forest area.

This disadvantage could be eliminated by cutting or by substituting forest cover with some other vegetative cover with

smaller evapotranspiration demand but, with only temporary increase in water yeald and by constant water quality decrease (Brechtel 1982,Djorović & Macan 1986).

The other way to increase the water yield from forest stands is by adequate forest management, where the basic aim is to produce a maximal possible water amount of good quality, instead of timber production as it is in traditional forest management.

Table 3 : Rainfall and water discharge for watersheds R-1 and R-2 for the period 1980 - 1989.

Water-shed	Year	Rainfall (mm)	Duration T (days)	$\bar{Q}$ ($l\ s^{-1}ha^{-1}$)	Qmin. ($l\ s^{-1}$)	Q max. ($l\ s^{-1}$)	Pe (mm)	$n(\frac{Pe}{P})$
R-1	1980	983.2	132.2	0.27	1.41	3.39	309.8	0.32
	1981	1122.7	158.5	0.35	1.06	6.87	480.9	0.43
	1982	783.0	87.8	0.28	1.05	4.64	210.3	0.27
	1983	787.8	83.8	0.26	1.24	8.52	187.3	0.24
	1984	827.9	118.5	0.22	1.24	2.33	223.5	0.27
	1985	768.3	159.9	0.14	0.45	4.03	102.1	0.13
	1986	928.7	163.5	0.19	0.28	2.69	272.6	0.29
	1987	935.3	193.8	0.15	0.20	1.81	252.4	0.27
	1988	899.8	190.5	0.11	0.21	1.14	184.1	0.20
	1989	798.4	206.8	0.12	0.18	1.69	198.8	0.28
Mean value		883.5	149.5	0.20	0.73	3.71	251.2	0.25
R-2	1980	1027.6	120.8	0.39	1.18	4.13	404.7	0.39
	1981	1177.3	152.7	0.52	1.06	7.68	688.6	0.58
	1982	785.8	71.9	0.46	1.01	7.34	282.5	0.36
	1983	812.6	64.2	0.47	1.66	15.11	259.4	0.32
	1984	875.9	96.2	0.39	1.67	3.78	329.5	0.38
	1985	703.9	107.7	0.23	0.33	2.67	210.7	0.30
	1986	956.8	129.6	0.26	1.06	2.73	287.8	0.30
	1987	993.9	146.6	0.34	0.61	2.95	434.1	0.44
	1988	946.8	138.5	0.19	0.18	2.22	232.2	0.24
	1989	840.1	140.5	0.25	0.36	4.50	305.7	0.36
Mean value		912.1	116.8	0.34	0.99	5.3	343.6	0.37

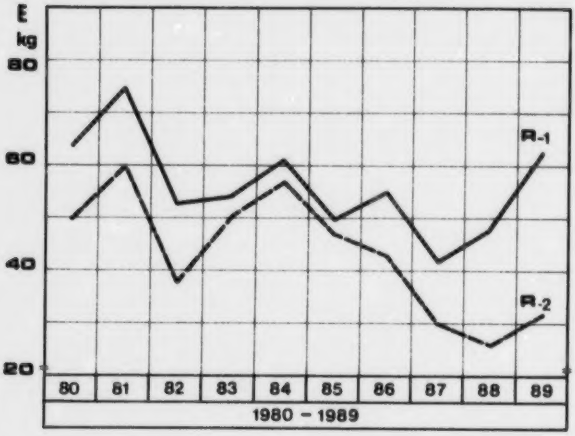

Figure 2 : Sediment discharge (E) from watershed R-1 (forest) and from watershed R-2 (grass).

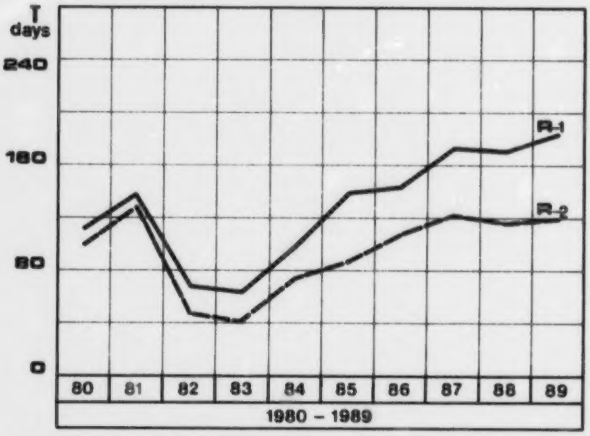

Figure 3: Water discharge duration (T) from watershed R-1(forest) and watershed R-2 (grass).

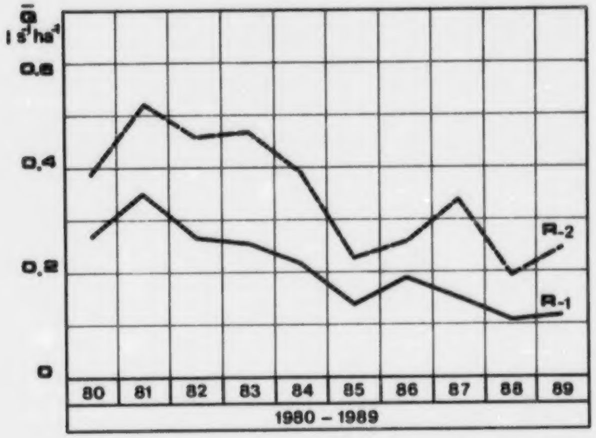

Figure 4 : Water discharge rate ($\bar{Q}$) for watersheds R-1 (forest) and watershed R-2 (grass).

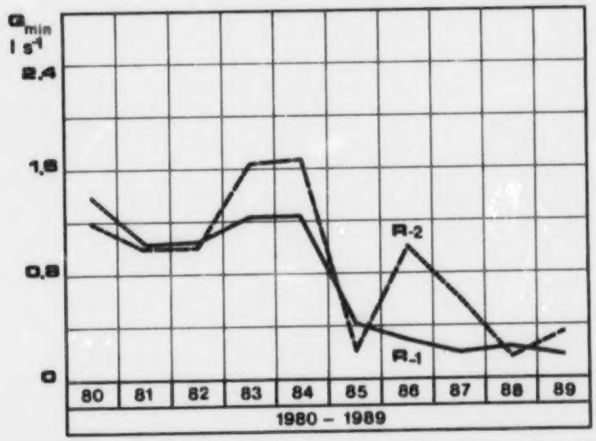

Figure 5: Water discharge minimum (Q min.) for experimental watersheds R-1 (forest) and R-2 (grass).

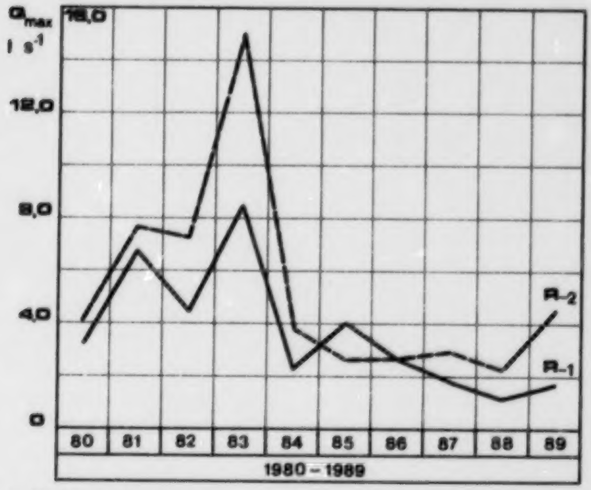

Figure 6 : Water discharge maximum (Q max.) for watershed R-1 (forest) and for watershed R-2 (grass).

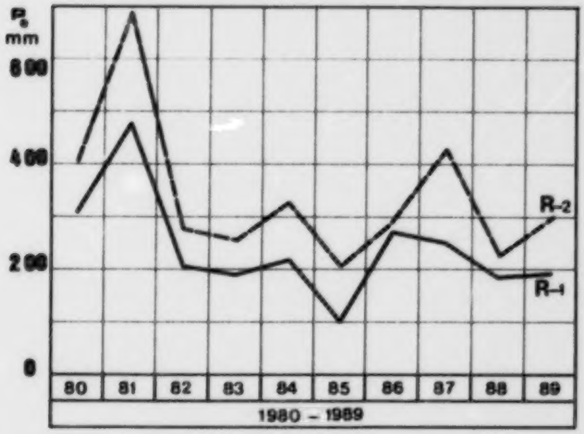

Figure 7 : Total water discharge (Pe) for watershed R-1 (forest) and watershed R-2 (grass).

CONCLUSIONS

The study of erosion control effects of forest and grass cover in two small watersheds during the period 198o - 1989, showes the real significant role of forest and grass cover on erosion and run off.

Sediment discharge for both watersheds is far under erosion tolerance of 2.o tons per ha annually (Djorović 1974), fig.2, table 2.

Total amount of annual water yield (Pe) is higher in grass watershed than in forest one, table 3, fig.7. Also, the rate of the flow and variation of the flow are higher in grass watershed than in forest one, table 3, fig. 4,5,6 .

Though the forest watershed yields smaller quantity of water than the watershed under grass cover, that water is of better quality, with moderite rate of flow and of longer duration,table 3, fig. 3, which are the most important flood control characteristics.

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SNOW PROPERTIES AND MOVEMENTS IN FORESTS OF DIFFERENT CLIMATIC REGIONS

Werner Frey and Bruno Salm

Federal Institute for Snow and Avalanche Research (FISAR)
7260 Weissfluhjoch-Davos, Switzerland

FDC: 111.784: 424.1: 111.82: (23)

SUMMARY

In many mountainous regions of the world forests are playing the most important role in avalanche control, i.e. to prevent formation of avalanches endangering settlements or traffic ways at the foot of mountains. Introducing the international ICSI-classification for snow and avalanches, the snow cover and climatic conditions leading to avalanches in forests are compared to the open land. An attempt is made to describe the main factors acting on snow cover development and avalanche formation in zones of different latitude and altitude.

Keywords: Protective forest, snow and avalanche classification

INTRODUCTION

A sufficiently dense, healthy forest prevents from avalanche starting. If regeneration of forests takes place in a sufficient way, the forest therefore is by far the most economic way of avalanche protection. Smaller avalanches originating from uphill will be stopped by the forest or flow through it without causing important damages. Fully developed, fast avalanches inevitably destroy the forest in their tracks. The interrelations between forests, snow, and avalanches are subject to extensive scientific work becoming more and more important, focussing also possible consequences of forest damages and forest decay (in der Gand and Kronfellner-Kraus 1984; Frey, Good and Frutiger 1987; Imbeck 1987).

Since snow and avalanche types vary quite widely with different climatic conditions, some aspects of snow and snow movements in regions unknown to a reader of scientific publications may make it difficult to understand all aspects. We propose therefore the wide use of the snow classification and the avalanche classification of ICSI (International Commission on Snow and Ice) also in forest sciences.

METHODS

In general, the natural snow cover consists of grains forming horizontal layers. These layers originate from different snowfall periods (storms). To characterize the snow quality in these layers, the classification of deposited snow is used. The ICSI-classification (CSI 1954, ICSI 1981) is cited in Table 1. Only the more important parts needed to describe the snow cover in the forest zone are mentioned.

Table 1: Classification of deposited snow according the ICSI-standard (CSI 1954, ICSI 1981)

Feature	Symbol	Subclassification a or 1	b.2	c.3	d.4	e.5
Grain shape	F	original shape	partly branched, slightly settled	rounded	faceted	ribbed cup shaped depth hoar
		new snow		old snow		
		(from left to right progressive metamorphism = m.)				
		<-- destructive m.----->		<-- constructive m.----->		
Grain size	D	<0.5mm very fine	0.5-1mm fine	1-2mm medium	2-4mm coarse	>4mm very coarse
Free Water	W	dry	moist snow, sticky	wet, water visible	very wet, water running off	slush, saturated
Cohesion (kN/m^2)	K	0-1 very low	1-7.5 low	7.5-25 medium	25-50 high	>50 very high
Hardness	R	very soft	soft	medium hard	hard	very hard
Hand test [object can be pushed into the snow with moderate force (30 N)]		fist	4 fingers	1 finger	pencil	knife
Density	G	(kg/m^3)				
Snow temperature	T	(°) (indicate position of measurement)				

For some details of the snow cover in forest stands, we obviously will use the terms of the mentioned classification. The avalanche classification (ICSI 1981) is divided into the morphological (Table 2) and the genetic classification on which we refer in chapters "Results" and "Conclusions".

A revised version of the ICSI snow classification will be published 1990 by the World Data Center for Glaciology CIRES, Box 449, University of Colorado, Boulder, CO 80309 USA.

Table 2: Morphological avalanche classification according the ICSI-standard (ICSI 1981)

Zone	Criterion	Alternative characteristrics, denominations and code	
Zone of origin	A Manner of starting	A1 starting from a point (loose-snow avalanche)	A2 starting from a line (slab avalanche) A3 soft A4 hard
	B Position of sliding	B1 within snow cover (surface-layer avalanche) B2 (new-snow fracture) B3 (old-snow fracture)	B4 on the ground (full-depth avalanche)
	C Liquid water in snow	C1 absent (dry-snow avalanche)	C2 present (wet-snow avalanche)
Zone of transition	D Form of path	D1 path on open slope (unconfined avalanche)	D2 path in gulley or channel (channelled avalanche)
	E Form of movement	E1 snow dust cloud (powder avalanche)	E2 flowing along the ground (flow avalanche)
Zone of deposition	F Surface roughness of the ground	F1 coarse (coarse deposit) F2 angular blocks F3 rounded clods	F4 fine (fine deposit)
	G Liquid water in snow debris at time of deposition	G1 absent (dry avalanche deposit)	G2 present (wet avalanche deposit)
	H Contamination of deposit	H1 no apparent contamination (clean avalanche)	H2 contamination present H3 rock debris, soil H4 branches, trees H5 debris of structures

RESULTS

On the Forest Snow Cover

In mountain regions of temperate climates, the snow cover in forest stands is often significantly different from the snow cover in open land. These differences have been investigated by many authors since more than a century (Woeikof 1889, Engler 1919, Kittredge 1953 - for more information see the review publication by Frey 1977). Newer publications give also quantitative information (Fiebiger 1978, Keller 1979, Tranquillini 1979, Imbeck 1987, Imbeck and Ott 1987). In Table 3 some important factors affecting depth and quality of the forest snow cover compared to the snow cover in the open land are shown.

Table 3: Factors affecting differences between a forest snow cover and a snow cover in the open land

Feature	Open land	Forest canopy
<u>Stable Factors</u>		
Altitude	Deeper snow cover and more dry snow with increasing altitude.	Less snow deposit compared to the open land.
Configuration of terrain	More open, even slopes.	Terrain more confined.
Roughness	More smooth ground.	Mostly more roughness.
<u>Variable Factors</u>		
Wind:	Disturbed by terrain.	Disturbed by terrain and forest canopy.
-Direction	Formation of cornices.	Changing more often.
-Velocity	High, no reduction.	Strong reduction, more turbulent winds.
Temperature: (see also next page)	High variation: especially in contact zone of air and snow.	Variation smoothed: especially in contact zone of air and snow.
Snowfall:	More snow on the ground forming homogeneous layers.	Loss of intercepted snow, great variability on small scale.
Radiation: (see next page for further information)	Sun radiation affected only by terrain forms; great longwave radiation loss favours constructive metamorphism and surface hoar formation.	Sun radiation also affected by trees; longwave radiation loss reduced and therefore reduced or no formation of surface hoar.

Radiation, Temperature, Snow Depth and Snowpack Stratification in a Spruce and in a Larch Forest

In a subalpine forest composed of larch and spruce trees near timberline at Davos, radiation and temperature have been measured in wintertime (unpublished results by courtesy of H. Gubler and of J. Rychetnik, FISAR).

In the deciduous larch forest, no significant differences could be found compared to the open field (reduction of incoming shortwave radiation by 20-30% in the forest, and an even smaller reduction of longwave radiation loss).

In midwinter and in denser parts of the spruce forest, differences have been significant compared to the open field: a reduction of up to 90% of incoming shortwave radiation and of longwave radiation loss. Changes of temperature of the snow cover surface have therefore been smoothed out by several degrees Centigrade with significant reduction of surface hoar formation.

Incoming shortwave radiation heats needles, branches and stems. Temperature crosses the melting point and intercepted snow (in the spruce forest up to 40 cm of new snow) is falling or dropping into the snow cover producing there a strong disturbance.

In the larch forest, mean snow depth has been reduced by 10-30% with small variations compared to the open field, whereas in the spruce forest snow depth has been reduced by up to 90% with enormous variations.

Differences in the structure of snow layers have been measured using a sledge-mounted FMCW radar moved over the snowpack (FMCW = Frequency modulated continous wave). This method gives an image of the stratigraphy of the snowpack without destructing it. Figures 1 and 2 show electromagnetic profiles of the snow cover stratification in an open field compared to larch and spruce forests near timberline (Figures by Gubler and Weilenmann 1986).

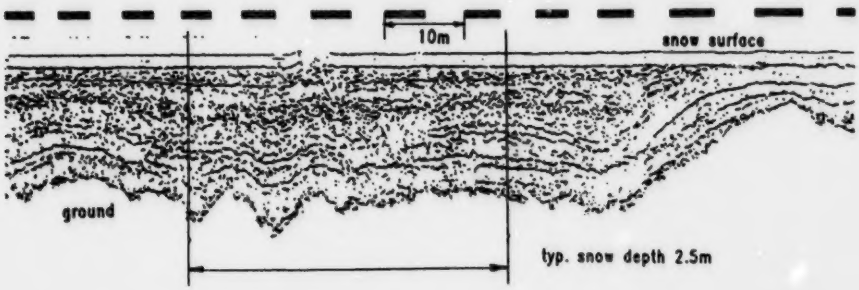

Figure 1: Electromagnetic profile showing the stratification of the midwinter snowpack in an open test field. Layering of the snowpack is obvious.

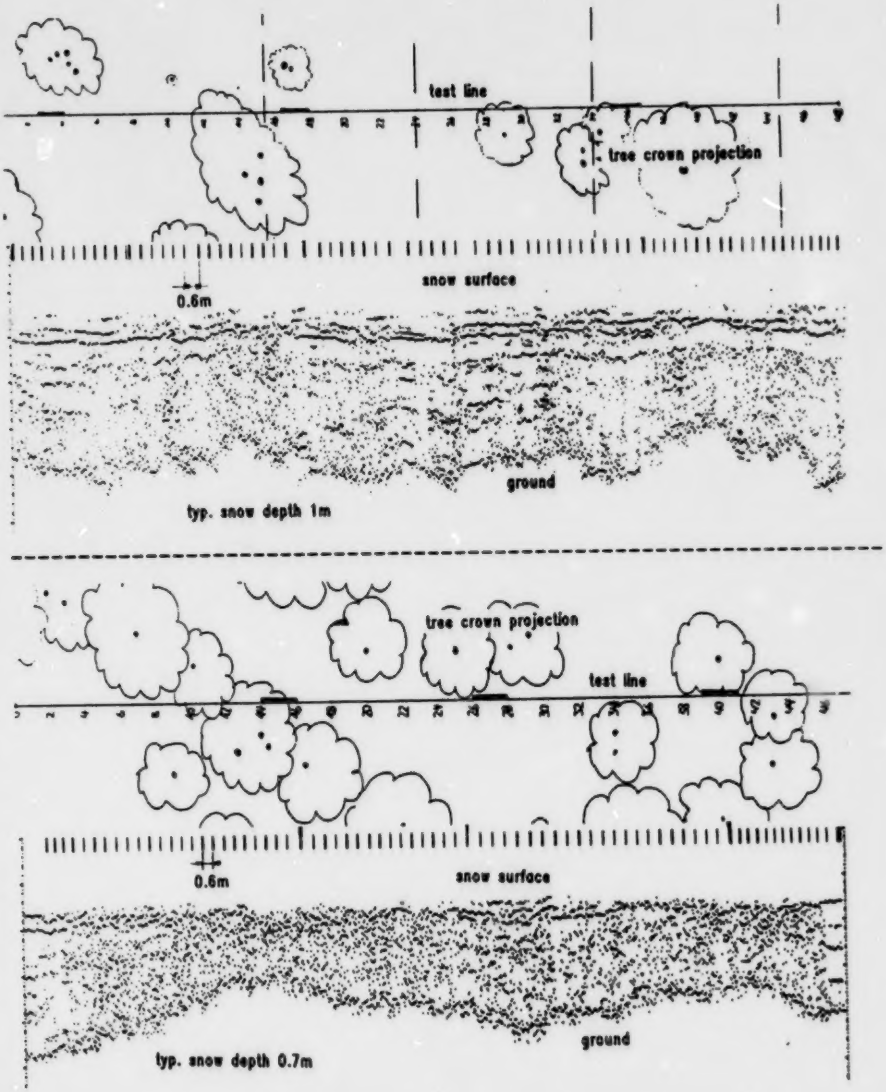

Figure 2: Electromagnetic profile of the midwinter snowpack in a larch forest (above) and in a spruce forest (below) at timberline. Note the differences in stratification, also comparing with the profile of the open test field (Figure 1).

Snow Cover and Avalanche Formation

Snow depth and genesis of avalanches may vary widely between open land and forest canopy (Frey 1977, de Quervain 1979, ICSI 1981, Imbeck 1987). Table 4 shows some of the main factors affecting snow cover and avalanche formation in the open land compared with the forest.

Table 4: Factors affecting the snow cover and avalanche formation in the open land compared with the forest

Factor	Open land	Forest canopy
Snow depth	In larger areas depending on terrain morphology only.	In general less snow, but enormous variation in depth (snow loss due to canopy interception)
Snow metamorphism	High due to undisturbed influence of radiation and air temperature.	Not so high, less faceted and ribbed forms because of reduced influence of radiation and air temperature.
Layer formation in the snow cover	Continuous layer formation possible in large areas. Formation of surface and depth hoar enhanced (weak layers).	Only in small scale possible due to strong variation in snow depth Layer formation also disturbed by parts of snow and meltwater falling from trees.
Creep and glide of the snow cover (slow snow movements with speed < 1cm/s)	Creep not disturbed by obstacles in the snow. Glide promoted by moist snow in the basal zone of the snow cover and by smooth ground. Glide may lead to avalanches.	Creep affected by trees and shrubs. Glide possible even in small openings. It may be promoted by the smoothed temperature regime in the forest. No big avalanches.
Types of avalanches (classifcation see Table 2)	Big size avalanches and all types possible (A1, A2, A3, A4). Slab avalanches important.	Mostly loose-snow av. (A1) of small size. Big slab avalanches only in openings with diameter > 40m.
Frequency and destructive force of avalanches	Frequency may be low, and avalanche size and velocity may lead to big destructive events.	Frequency may be low or high, avalanches are mostly slow, small-sized and less destructive

Vegetation Types, Snow Cover and Avalanche Formation

Different vegetation types lead to different snow depth, snow cover quality and different conditions for avalanche formation. Table 5 shows some factors in these interrelations.

Table 5: Influence of different vegetation types on snow depth, snow cover quality and avalanche formation

Vegetation type	Snow cover	Avalanches
Grass	Formation of continuous layers. Occurence of depth hoar	Promoting snow glide if the terrain is smooth. Often full-depth and unconfined av. Dynamic forces of avalanches not reduced.
Shrubs	Snow depth equal or higher than in the open land (catch of wind-swept snow). Constructive metamorphism in holes caused by branches.	Reduced avalanche formation if not snow covered. Promoted avalanche formation (slab avalanches A2, A3, A4) if snow covered due to formation of weak layers. Triggering of loose-snow avalanches by moving branches or falling snow pieces. Dynamic forces of avalanches hardly reduced.
Dense deciduous forest	Reduced snow depth and reduced metamorphism. Weak layers possible only in a small scale.	Glide possible on sun-exposed slopes. Mostly loose-snow avalanches or slab and full-depth avalanches. Dynamic forces of avalanches reduced.
Dense coniferous forest	Strong reduction in snow depth, big variability in snow depth. Reduced metamorphism.	Glide hardly occuring. Only few avalanches of minimal size occuring: loose-snow and surface avalanches. Dynamic forces of avalanches strongly reduced.
Openings in forests (Diameter 1-2 x tree height)	Snow depth highly increased compared to the forest. Constructive metamorphism leads to weak layers.	Glide frequent (sunny slopes) All avalanche types possible (A1, A2, A3, A4). Dynamic forces of avalanches moderatly reduced

CONCLUSIONS

General Features for Avalanches Starting in the Forest Zone

Depth and metamorphism of the snow cover cause avalanche danger. Forests can prevent avalanche formation, but the protective influence of forests depends on several factors. We try to list and to explain the most important of these factors looking especially at the influence of forests.

General topographic situation:
- Configuration of terrain: forest influence important in sites where the danger of avalanche formation is increased (e.g. cornice sites, steeper parts, smooth terrain).
- Inclination: forest influence important not only in generally steeper parts, but also at critical inclinations of 25-35° where avalanche formation in the open occurs quite rarely (statistical return period > 30 years).
- Exposition: on sunny slopes snow glide and wet-snow avalanche formation are generally enhanced and therefore also small-scaled influence of trees becomes important.
- Roughness: forest influence more important on smooth ground, especially concerning snow glide and formation of full-depth avalanches.

Type of forest:
- Coniferous forest: compared to open fields, influence is decisive on snow depth, formation of surface or depth hoar and stratification and therefore a significant decrease in avalanche formation.
- Deciduous forest: influence only moderate on snow depth, formation of surface hoar and stratification and therefore only a moderate decrease in avalanche formation. In more critical situations the influence of deciduous forests on avalanche formation is minimized.
- Mixed forests: Intermediate influence on avalanche formation.

Stand characteristics:
- Structure of the forest: single storied stands are in general less effective in preventing avalanche formation than multilayered and clustered stands.
- Regeneration: saplings protect from the formation of surface-layer avalanches if their height reaches about actual snow depth. Regeneration nuclei should be small but spread over the whole area of the protective forest.

Dimension and form of openings:
- General demand: avalanches starting in openings of a forest canopy should not be able to destroy downhill forests on their track or even gain energy there.
- Diameter and form of openings: downslope range of the openings should not exceed 40 m or at most 1-2 times the height of adjacent trees. Horizontal shape seems not so much limited. If needed for regeneration, extension of openings should be searched in horizontal direction.

Geographical Features

The type of climate is a decisive factor for snow depth, snow metamorphism, stability of snowpack, and avalanche activity. The generally higher amount of precipitation in maritime types of climate results in a deeper snowcover with more moist or wet snow than in continental types of climate.

Snow metamorphism is a result of the energy balance resulting of the heat flow at the surface of the snowpack due to radiation or convection and the heat flow at the contact zone of snow and soil. This energy balance is influenced by geographical latitude and by altitude. Since forest influence on the snow cover is changing with latitude and altitude, forest influence on avalanche activity also is not the same in different regions of the world. Figure 3 is an attempt to classify energy flow, metamorphism of the snowpack and resulting forest influences on snow cover and avalanche activity for different latitudes and altitudes.

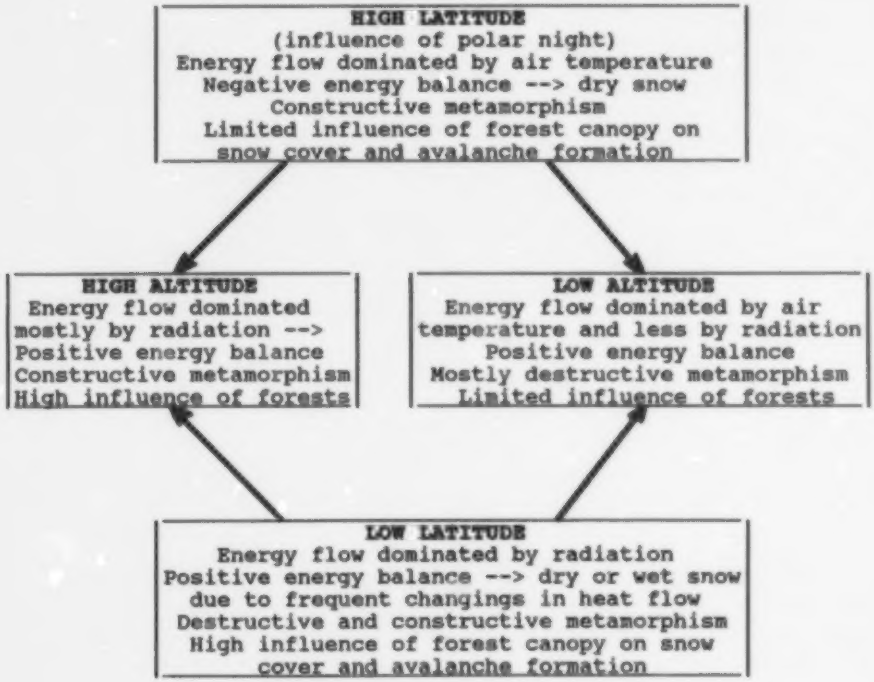

Figure 3: Energy balance and metamorphism of the snowpack, avalanche activity and influence of the forest on these factors in different latitudes and altitudes.

Main information used for Chapter "Conclusions" was found in Wakabayashi (1975), Frey (1977 and 1979), de Quervain (1979), Hackett (1980), ICSI (1981), Nakamura (1980), Armstrong and Armstrong (1987), Imbeck (1987), Hestnes and Sandersen (1987), Voitkovskiy (1987).

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EFFECTIVENESS OF REFORESTATION IN PREVENTION AND CONTROL OF LANDSLIDING DURING LARGE CYCLONIC STORMS

Christopher Phillips, Michael Marden, and Andrew Pearce

Scientists and Director
Forest Research Institute

Christchurch, New Zealand

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SUMMARY

The effectiveness of a reforestation project in the eastern North Island, New Zealand, in prevention and control of landsliding during large cyclonic storms proved difficult to quantify. However, earthflow movement rates under forest were less than those under grass. Onset of movement of the forested earthflows lagged several weeks behind the response of grassed earthflows during large storms, but both returned to pre-storm rates in about the same time interval. Pine plantations <6 years old gave a similar level of protection against landsliding as grass cover on slopes of similar aspect, steepness, and rock type. Slopes under these young stands had a landslide density of 0.62/ha as a result of Cyclone Bola, a severe cyclonic storm event in 1988. Plantations 6-8 years old provided an intermediate level of protection from Cyclone Bola, with a landslide density of 0.21/ha. Plantations older than 8 years gave 10 times the protection of younger stands, with a landslide density of less than 0.06.

Keywords: earthflows; landslides; slope stability; afforestation.

INTRODUCTION

Between 1960 and 1986 about 400 km^2 of rapidly eroding hill country in the Raukumara Peninsula, eastern North Island, New Zealand, were reforested with plantations of predominantly *Pinus radiata*. The primary objectives of the planting programme were to reduce on-site erosion, decrease downstream sediment transport and aggradation of major river channels, and reduce the impacts of floods. Using data collected from Mangatu Forest, the on-site effects of the reforestation programme on hydrology and erosion were discussed by O'Loughlin (1984) and Pearce *et al.* (1987).

In March 1988, a cyclonic rainstorm hit the eastern North Island of New Zealand, severely affecting the Raukumara Peninsula (Fig. 1). Cyclone Bola caused widespread landsliding and flooding over an area of 650 km^2. Pasture, forest, horticultural land, and communications in this area of the eastern North Island all suffered extensive damage estimated to have cost $100 million.

This paper reviews earlier and current work on the differences between reforested and unforested areas in earthflow movement rates, landslide densities, and eroded area caused by large magnitude, low frequency cyclonic storms. Cyclone Bola and three earlier storms are used as examples. Comments are made on the effectiveness of reforestation in modifying and reducing the impacts of such storm events.

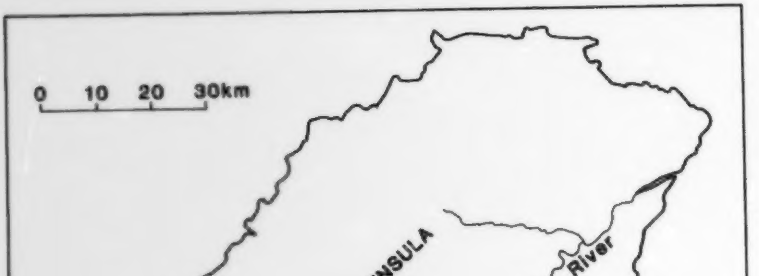

Figure 1: Location map showing place names.

STUDY AREA

The Raukumara Peninsula in eastern North Island lies at latitude 39°S and longitude 178° E. The region covers approximately 650 km^2 and has an extremely variable landscape closely correlated with geology. Deposits of thick (0.5-3.0 m) late-Quaternary volcanic ash and old forest soils are well preserved on ridge tops and gently sloping dip slopes but are considerably thinner on steeper scarp slopes. On lower slopes the volcanic ash deposits have been removed, largely as a result of mass movement associated with stream dissection.

Mangatu Forest (120 km^2) and Tokomaru Forest (80 km^2) are located in the headwater catchments of Waipaoa River and Mata River, respectively. These forests are mainly *Pinus radiata* ranging from 1 to 29 yr old.

The climate is warm temperate maritime, with moist summers and cool wet winters. Mean annual rainfall varies from about 700 mm at the coast to 2500 mm at higher altitudes (New Zealand Meteorological Service 1973). Lengthy periods of little or no rain are common during January to April (mid-summer to late autumn). The region has a history of severe storms, many of which are cyclones of tropical origin. Often the south-eastward movement of these cyclones is stalled by freak weather conditions, resulting in large rainfalls in the northern and eastern North Island. These extra-tropical cyclones occur about once every 12 yr on average (New Zealand Meteorological Society 1988).

METHODS

The effectiveness of forest cover in reducing the impacts of large magnitude, low frequency cyclonic events was assessed by several methods. The principal method was landslide inventory and density counts from aerial photographs. Surface and sub-surface movement on earthflows was also monitored. General field reconnaissance was carried out for many areas throughout the region after each storm.

Landslide densities were counted on pre- and post-Cyclone Bola aerial photographs of 11 sample areas totalling 53 km^2 from different parts of the region with different vegetation. Vegetation covers assessed were pasture and exotic pine plantations at three stages of growth (<6 yr, 6-8 yr, and greater than 8-yr-old). For different sample areas, but using the same vegetation cover groups, the surface extent of erosion scars before and after Cyclone Bola was calculated by the dot grid method for 53 039 ha. The volume removed by landsliding was calculated using eroded area and a mean depth of 0.85 m (measured from 100 landslides). Areas of windthrow and extensive areas of surface fissuring beneath standing trees were not assessed. At one locality in Tokomaru Forest, landslide inventories and counting of landslides on aerial photographs had been carried out for two earlier storms in 1980 and 1982.

Earthflow movement rates have been studied in Mangatu Forest for over 10 yr (Zhang 1987; Zhang *et al.* unpubl. data). Stake arrays measured by electronic distance measuring survey equipment (EDM) and nests of electrolytic tiltmeters (Zhang 1987) were used to study surface and sub-surface movement, respectively.

PREVIOUS STORM HISTORY

History

Four major periods of erosion and sedimentation in the eastern North Island of New Zealand have been identified since the 13th century, each postulated as being primarily the result of a sustained increase in the frequency of major rainstorms related to long-term climatic fluctuations (Grant 1981). A fifth period is considered by Grant to be currently in progress. During the last decade, four storms - in December 1980, April 1982 (Cyclone Bernie), July 1985, and March 1988 (Cyclone Bola) - have caused severe damage to parts of the Raukumara Peninsula. In some, but not all, areas successive storms caused additional damage. Although the intensities and durations varied widely between each storm and between localities, the storms each had magnitudes equivalent to a recurrence interval of between 15 and 100 yr.

Recent Storms

In December 1980, a storm arising from a stationary front released approximately 500 mm of rain over a period of a week on the headwaters of the major rivers draining the Raukumara Peninsula. Extensive downstream flooding resulted. Landslide damage, however, was restricted to the steeper headwater catchments. The storm was centred over the Waitahaia River catchment, which received 580 mm of rain in 8 days, 330 mm of which fell in 2 days. Maximum rainfall intensities reached 265 mm in 24 h and 15 mm in 6 min (Phillips 1988).

In April 1982, Cyclone Bernie (Revell & Ward 1982) moved eastwards across the North Island, causing widespread damage mostly from associated gale-force winds. In the Waitahaia River catchment 220 mm of rain was recorded in 3 days. The maximum 24-h total was 188 mm, and the maximum hourly rainfall was 15 mm. In this area far less landslide damage occurred than in 1980, though the bed elevations and channel morphology of the streams were changed. Severe windthrow was experienced in both indigenous and exotic forests in other parts of the North Island. In the Raukumara Peninsula windthrow occurred mainly in the western indigenous forests. Stem wrenching was prevalent in young pine plantations less than about 5 yr old.

In July 1985, a further storm centred to the south of Gisborne over the Ngatapa area, caused extensive shallow landsliding on pastoral farmland. The streams and rivers draining the area flooded severely.

Cyclone Bola, the most recent storm, yielded 5-day rainfall totals in excess of 900 mm for some areas. Typically, though, the rainfall varied between 300 mm and 600 mm. Rivers rose to levels not exceeded since 1876, and the river flats and flood plains were damaged by flood water and silt more severely than at any time since 1948 (Hicks 1989). In the Waitahaia River catchment rainfall was about 400 mm. The estimated return period of this event, calculated from 24-h rainfall intensities and depth-duration-frequency tables, was greater than 100 yr (B. Turnpenny, Water Resources Manager, Gisborne District Council).

GEOMORPHIC EFFECTS OF RECENT STORMS

Hillslope Processes

Landsliding

In each storm, erosion occurred mainly in the form of landsliding on the steeper hillslopes and as earthflows and slumps on the more gentle slopes. Shallow translational landslides of the debris slide - flow-avalanche types were extremely common where excess pore-water pressures mobilised the shallow regolith overlying relatively impermeable bedrock. These features were easy to see on aerial photographs. Less obvious on aerial photographs were the numerous surface fissures and cracks associated with re-activation of earthflows and slumps. Very large, isolated, deep-seated slumps and slump-flows occurred throughout the region. These large features often blocked streams, forming small lakes.

Earthflows

The impact of large-magnitude storms on the mechanics of earthflow movement is difficult to quantify. The various threshold conditions which appear to govern the initiation and cessation of movement are not fully understood. It is considered that movement begins once the water content of the soil approaches some value less than but close to saturation. Whether the onset of movement is associated with rapid or slow pore-water pressure changes is not certain. Thus, when a large storm event occurs, the previous soil moisture conditions may govern the earthflow response. Alternatively, there may be a lag of days, weeks, or months before movement is initiated.

Surface movement data collected from grassed earthflows generally show a correlation between rainfall from large storms and the movement of individual pegs on the surface of the flow. However, some pegs show large increases in movement rate after a major storm event, and other pegs show no increase (Table 1). The data also suggest that some zones of the flow

do not begin movement for several months after a large storm. This complex response is obviously related to the large spatial and temporal variation in threshold conditions within the earthflow. Sliding on basal and lateral shear planes accounted for 75-95% of movement (Zhang *et al.* unpubl. data). Mean monthly surface movement rates for grassed earthflows were 2-3 orders of magnitude greater (c. 1 m/month) than for forested earthflows (c. 5-10 x 10^{-3} m/month). On forested earthflows the lag time between rainfall and onset of movement was 2-6 weeks longer than on grassed earthflows. This may be related to drier soil conditions and a larger soil moisture deficit to be made up on forested earthflows before the movement threshold conditions are reached. Both forested and grassed earthflows which showed increased movement rates as a result of a large storm returned to pre-storm rates over a similar time span (Fig. 2).

Table 1: Surface movements (metres) of selected pegs on grassed Wether Run Earthflow Complex.

Series	Date	Peg Number			
		7500 (m)	7579 (m)	7582 (m)	7509 (m)
1-2	Jun 1983 - Sep 1983	0.03	0.10	0.07	0.10
2-3	Sep 1983 - Dec 1983	0.01	0.18	0.05	0.26
3-4	Dec 1983 - Mar 1984	0.04	0.42	0.08	0.14
4-5	Mar 1984 - Jun 1984	0.16	2.06	0.66	0.45
5-6	Jun 1984 - Sep 1984	0.13	3.97	1.69	1.84
6-7	Sep 1984 - Dec 1984	0.04	3.09	1.45	2.04
7-8	Dec 1984 - Mar 1985	0.02	0.17	0.09	0.01
8-9 *	Mar 1985 - Nov 1985	} 0.21	10.26	5.41	7.28
9-10	Nov 1985 - May 1986		0.78	0.50	0.20
10-11	May 1986 - Dec 1986	0.12	6.30	4.29	2.69
11-12	Dec 1986 - May 1987	0.04	3.46	2.11	0.08
12-13	May 1987 - Nov 1987	0.06	9.73	6.63	0.34
13-14 *	Nov 1987 - May 1988	23.73	6.93	6.10	1.90
14-15	May 1988 - Nov 1988	0.05	5.20	5.52	19.74
15-16	Nov 1988 - May 1989	0.06	0.16	0.08	2.80
16-17	May 1989 - Nov 1989	0.27	0.11	0.25	19.84

* Periods in which storms occurred

} Aggregated movement over more than one survey series

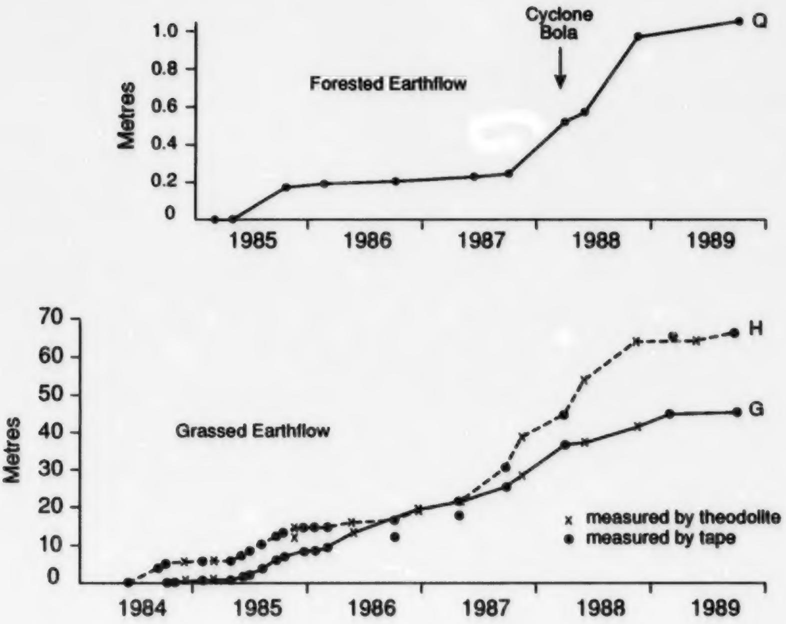

Figure 2: Cumulative surface displacement of tiltmeter holes on grassed earthflows (G,H) and forested earthflow (Q). Note vertical areas are different scales.

Vegetation-Landslide Relationships

Earlier studies on the effects of forest cover on slope stability

Forests alter the water balance characteristic under pasture by increasing interception losses and reducing transpiration (Pearce *et al.* 1987). The soil profile under forests in the study region was substantially drier for much of the year than it would have been under pasture. Further, the winter period of high soil water content under forest was approximately 3-4 months compared to 6-8 months under pasture. Runoff was also reduced by about 25-30% (Pearce *et al.* 1987).

Surface movement on forested earthflows is generally less than that on unforested slopes on similar terrain (Pearce *et al.* 1987). Slower rates of surface and sub-surface movement for forested earthflows than for unforested earthflows were considered a result of both drier soil conditions and the retarding effect of interlocking tree-root networks (O'Loughlin & Zhang 1986). Roots probably contribute to the stabilisation of earthflows by creating a reinforced upper soil layer 1.0 to 1.5 m thick which possesses relatively high lateral (tensional) strength as well as enhanced shear strength. On most slopes, the upper zone of an earthflow undergoes episodes of bending, compression, and extension as concave and convex profile sections of slope are traversed. The more rigid, root-reinforced upper soil layer of forested flows resists these deformations and reduces earthflow velocities (Zhang *et al.*unpubl. data).

Studies on root development and biomass at Mangatu Forest indicate that *Pinus radiata* root biomass increases at rates of 1-2 t/ha/yr from time of planting to age 8-10 yr, and then at 3-4 t/ha/yr up to at least 25 yr (Watson & O'Loughlin in press). By age 20, root systems have a mass of about 100 t/ha and occupy about 2 % of the upper 1 m of the soil profile (O'Loughlin & Zhang 1986). The increase in root biomass from about age 8-10 yr and increased rainfall interception by the closed canopy enhance slope stability and reduce the likelihood of shallow landsliding during storm events.

In areas of shallow soils, rapid shallow (c. 1 m) mass-wasting occurs in the form of debris slides and debris avalanches. These are commonly triggered in non-cohesive soil on slopes over 25° by rainfalls of about 80 mm in 24 h (O'Loughlin & Zhang 1986). Often the basal failure plane is at a soil-bedrock interface or soil-indurated substratum less than 2 m beneath the surface. In these areas root systems are usually plate-like, and roots seldom penetrate beyond the soil-bedrock interface.

The effect of catchment vegetation cover on activity in stream beds is more difficult to assess quantitatively. In upper, totally reforested catchment areas the reduction in supply of sediment from hillslopes to streams by mass-wasting processes has changed aggrading, braided stream channels to degrading channels with reduced braiding and a trend towards a single incised channel. Very recent stream terraces are no longer subjected to periodic inundation during flood events and now support a vegetation cover.

Current studies

After Cyclone Bola an assessment of landslide-vegetation relationships was made for areas where shallow soils exist on steep slopes. On such terrain, slopes with pine plantations <6 yr old had a mean landslide density of 0.62 landslides/ha, similar to that for adjacent slopes in pasture (0.68 landslides/ha). This corresponds to a 343% increase over pre-Cyclone Bola landslide density for slopes under stands of this age and 300% for slopes under pasture. Mean surface erosion volumes/hectare calculated from eroded area caused by landsliding for this one event were 790 m^3/ha for pine plantations <6 yr and 916 m^3/ha for pastured slopes. This indicates that reforestation does little to enhance slope stability or reduce surface erosion within 6 yr of establishment.

Mean landslide density for slopes under stands of pines 6-8 yr old (0.21 landslides/ha) was one-third that of younger stands on similar terrain. The net increase in landslide area as a direct result of Cyclone Bola was less than one-half that of the younger stands (3.5%), and the surface erosion volume dropped to a mean of 370 m^3/ha. In stands of this age the combined effects of "sinker" root development, increased root biomass, soil-water utilisation, and canopy closure provide sufficient increased slope stability to reduce both the incidence of shallow landsliding and the severity of surface erosion processes.

Mature pine plantations gave the most protection from Cyclone Bola. Slopes under pine plantations >8 yr old had less than 0.06 landslides/ha and, on an area basis, showed a 0.6% increase in landslide area after Cyclone Bola (Fig. 3). This was one-tenth of the landslide density for slopes under pines <6 yr old. Surface erosion due to landsliding was reduced from a mean of 790 m^3/ha in <6-yr-old stands to 48 m^3/ha. At age 8 yr, root systems have developed strong lateral structural roots which extend up to 4 m from the root bole and vertical "sinker" roots which penetrate to 2 m depth. Interlocking and overlap between adjacent tree-root networks reinforce the upper soil horizons and prevent the widespread development of shallow landsliding. Slope stability improves until about age 15 yr. Further improvements in older stands due solely to root systems are probably negligible, though the influence of understorey vegetation is likely to increase.

Figure 3: Landslides caused by Cyclone Bola (5-9 March 1988) on slopes under pasture and 8-yr-old *Pinus radiata*. Photograph taken 20 months after Cyclone Bola. Note: the new plantings on the pasture are post-Bola. *Photo: David Blake*.

Although plantations provided effective protection from shallow landslides, they have made no discernible difference to the pattern and rates of expansion of major gully-mass-movement features. Some mass-movement complexes have expanded into successfully established adjacent forest stands, and continue to expand as a result of higher frequency, lower magnitude events. These complexes continue to be the largest single-point sources of sediment transferred to rivers.

CONCLUSIONS

Pine plantations <6 yr old were largely ineffective for stabilising earthflows but gave some protection against surface erosion processes and shallow landsliding except during periods of soil saturation and high pore-water pressures, usually a result of cyclonic rainfall.

Pine plantations between the ages of 6 and 8 yr provided more stability than younger stands to earthflows and slopes prone to shallow landsliding.

Mature pine plantations (>8 yr old) reduced earthflow movement rates by one-tenth that on adjacent grassed slopes in similar terrain. On steep hill country with mature pine stands, surface erosion in the form of shallow landsliding resulting from Cyclone Bola was one-twentieth of that on adjacent pasture-covered slopes.

The effectiveness of reforestation in reducing the impacts of individual large storms on landsliding is difficult to predict because of the spatial and temporal variability of physical site conditions. It is also difficult to predict the outcome of subsequent events of similar magnitude on an area previously affected by large storms. Data from our studies indicated that once hillslope sites had failed in one event, the focus of geomorphic impact in later events shifts from slope erosion to changes in stream sedimentation and morphology. These findings are similar to those of Newson (1980) and others (e.g., Lehre 1981).

This study shows that reforestation can reduce the erosional impacts of large rainstorms, but that effective protection is not provided until plantations have reached a specific age and degree of development. Their threshold age or degree of development will probably vary according to factors such as forest type and rate of growth.

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COMPUTER SIMULATION OF LANDSLIDE MOTION

Kyoji SASSA

A. Professor, Disaster Prevention Research Institute
Kyoto University, Uji, Kyoto, Japan

FDC: 114.1: 116.3

SUMMARY

Assessment of the motion of a potential landslide is one of the most economical disaster-reduction-measures. The author studied the mechanism of long-travelling landslide and also how to decide the coefficient of friction during motion by means of a newly developed high-speed ring shear apparatus and others.

Together with those experimental research, the author developed a new computer simulation of the motion of landslide in reference with the already-developed computer simulation of water flow. This simulation is able to express the **"softness"** of landslide mass as well as the **"slipperiness"** of the slope.

The application of this computer simulation to the Ontake long-travelling landslide reproduced the long and complicate motion of the landslide in computer.

THE MECHANISM OF LONG-TRAVELLING LANDSLIDE

When a landslide mass moves down on a slope, sometimes a moving mass scrapes the slope surface, and sometimes it leaves a part of mass on the slope. Two cases are shown in Fig.1.

Case A:

When the slope is less saturated, pore pressure inside the moving mass dissipates to the slope. In this case the peak value of pore pressure will appear inside the sliding mass, the shear surface will be formed along the peak pore pressure line and the mass below the line will be left on the slope. Since the pore pressure dissipates gradually during motion, the landslide will not travel so much.

Case B:

When the slope is much saturated, the moving mass causes a high pore water pressure inside the slope. Then, the sliding surface will be formed along the peak pore pressure line, if the slope material is not specially strong, but almost same with the moving material. This situation is similar to the slip of a car on saturated muddy roads. Pore pressure is supplied from the slope, accordingly the landslide mass can travel much so long as the much-saturated slope continues. Therefore, the long-travelling landslide should be related to Case B. The author studied the case experimentally.

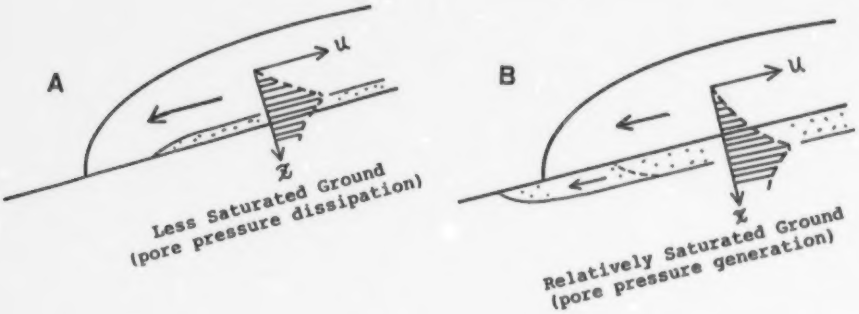
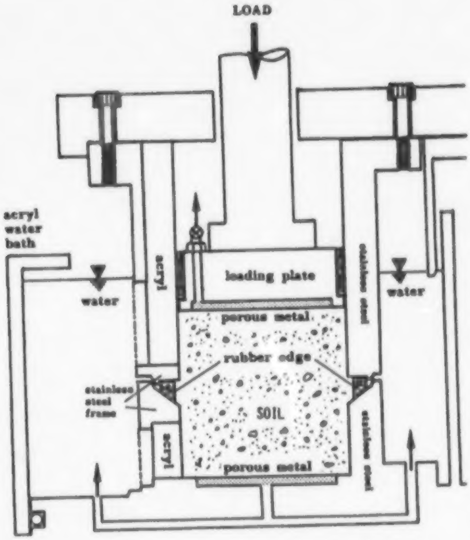


Fig. 1 Two Cases of the Motion of Landslide

A New Ring Shear Apparatus

The author developed a new high speed ring shear apparatus (for low normal stress of 0 - 0.4 kgf/cm^2) to study the friction angle during fast motion of debris flows in 1984. The test results showed that the effective friction angle during motion is almost independent of shear speed (Sassa, 1984). Then, it clearly denied the low value of the effective friccion angle during fast motion of debris flows ealier suggested by Bagnold, 1954 . At the same year Hungr and Morgenstern, 1984 presented the same result that the friction angle during motion is independent of shear speed in use of a high speed ring shear apparatus for a higher normal stress of 0 - 2 kgf/cm^2. Therefore, the apparent low value of friction angle during landslides and debris flows should be caused by high water pressure during motion(Sassa, 1985, 1988). To make further research on friction angle and pore pressure during the motion of landslide, Sassa, 1988 produced another advanced type of high speed ring shear apparatus for a high normal stress (0 - 4 kgf/cm^2) with 2 servo-control moters and one servo-control air regulator. Fig.2 is the schematic figure of the apparatus and the detailed section of the sample box. The sample box is a doughnut shape, the inside-diameter is 21 cm, the outside-diameter is 33 cm, the shear area is 590 cm^2, the standard sample hight is 6 cm. The normal stress is supplied by 6 air-pistons. The lower half of the sample box is rotated, while the upper half is connected to the main body through a load cell to measure shear stress. In use of 2 servo--mortors and 1 air servo-control regulator, the constant-normal-stress test, the constant-volume-test, the constant-shear-speed-test, the constant-shear--stress test can be done, while the gap of two rings is kept strictly constant in one servo-control motor. Fig.3 shows sheared samples after test, where the loading unit and the upper half of sample box were removed. In use of this new appratus, the author measured the variation of shear resistance during a rapid loading of normal stress.



Detailed Section of the Sample Box

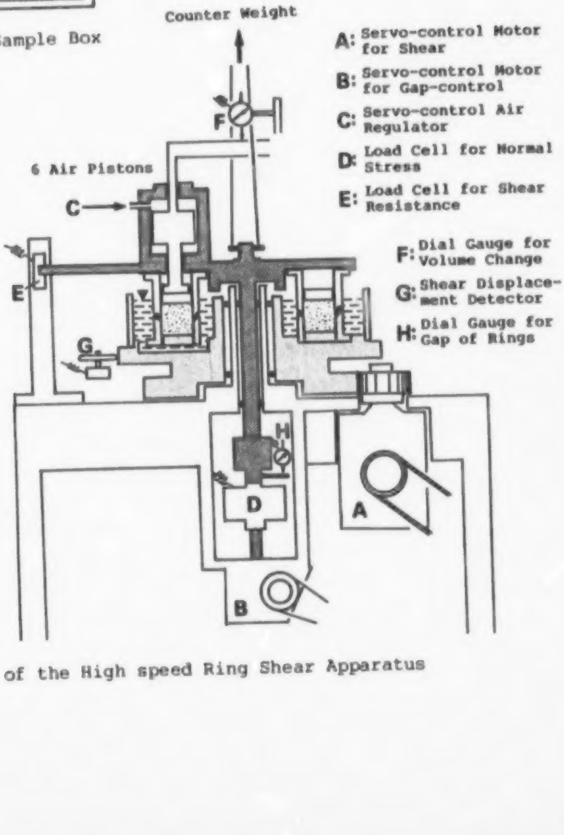
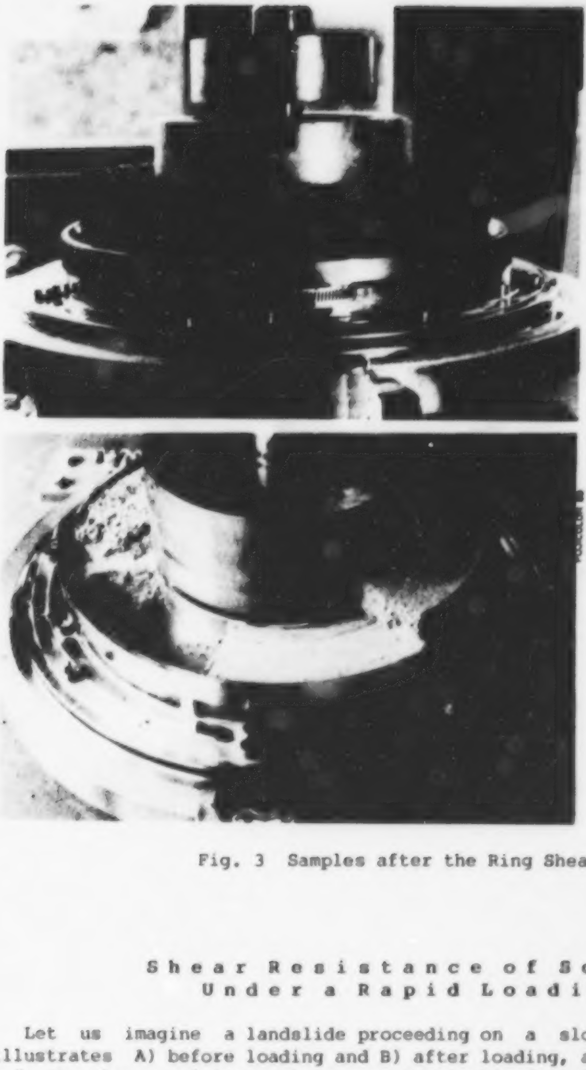


Fig. 2 Outline of the High speed Ring Shear Apparatus



Saturated deposit taken from the Denjou torrent over which the Ontake landslide mass travelled.

Unsaturated soil taken from the Jizukiyama landslide in Nagano-city, 1985

Fig. 3 Samples after the Ring Shear Test

Shear Resistance of Soils Under a Rapid Loading

Let us imagine a landslide proceeding on a slope in Fig.4, which illustrates A) before loading and B) after loading, and examine the stress and the shear resistance at the point P in Fig.5. P_A and P_B in Fig.5 are the stress of Point P before/after loading. The stress increases along a line of gradient θ because the normal stress increment is $\Delta W \cos\theta$ and the shear stress increment is $\Delta W \sin\theta$. When we measure the shear resistance of soils at Point P before loading, it is given by S_1 on the failure envelope. When we continually measure the shear resistance at Point P

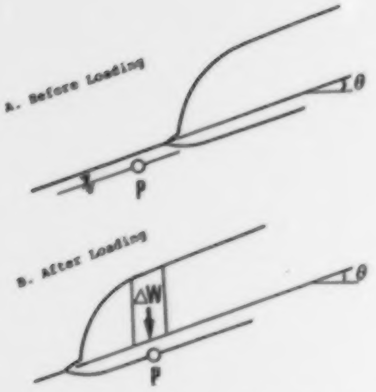


Fig. 4 Loading on a Slope by a Moving Landslide

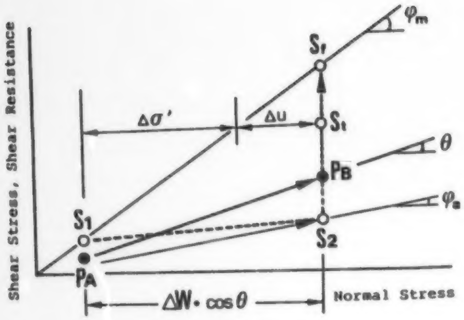


Fig. 5 Stress and Shear Resistance during Rapid Loading

during loading, the shear resistance changes from S_1 to S_f along the failure envelope as the stress changes from P_A to P_B if no pore pressure is generated during loading. However, when the slope is saturated, pore pressure will be usually generated during rapid loading. In this case the shear resistance just after loading will be expressed by S_2 for example. If the loaded stress is kept constant, the generated pore pressure will dissipate gradually, and the shear strength will increase with dissipation of pore pressure and reach the shear resistance on the failure envelope S_f finally. The shear resistance S_t at time t after loading and the pore pressure (Δu) and the effective normal stress increment ($\Delta\sigma'$) at that time are shown in Fig.5.

Since the stress P_B is greater than the shear resistance S_2, the mass will continue its motion scraping a layer over the point P. The apparent friction angle is ϕ_a to connect the origin to S_2, it is much smaller than the real friction angle ϕ_m (the suffix "m" means the friction angle during motion). As suggested from the figure, the apparent friction angle gets smaller as the initial stress of P (P_A) is smaller (namely the saturated zone is shallower), and as the loaded normal stress is greater (the moved landslide is greater). However, the most important factor on the apparent friction angle is the degree of saturation, which was studied by Sassa, 1985, 1988.

The author tried to reproduce this situation in use of the ring shear apparatus, and performed a test in the following procedure in use of the Toyoura standard sand (quartz sea shore sand, the grain size is 0.1-0.3 mm).

1) Shear the sample under 0.5 kgf/cm^2 normal stress at the shear speed of 0.01 cm/sec, and measure the shear resistance.
2) Keep shearing and increase the normal stress up to 3.5 kgf/cm^2 rapidly, and continue to measure the shear resistance.
3) Keep normal stress constant and continue to measure the shear resistance until the value will reach a constant.
4) After reaching a constant value, decrease normal stress slowly to obtain the failure envelope under the conditon of no-pore pressure.

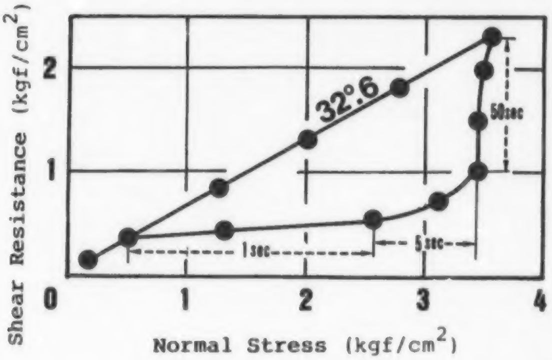


Fig. 6 Rapid Loading Test of the Saturated Toyoura Standard Sands (Grain size: 0.1 - 0.3 mm, Void ratio: 0.74-0.79)

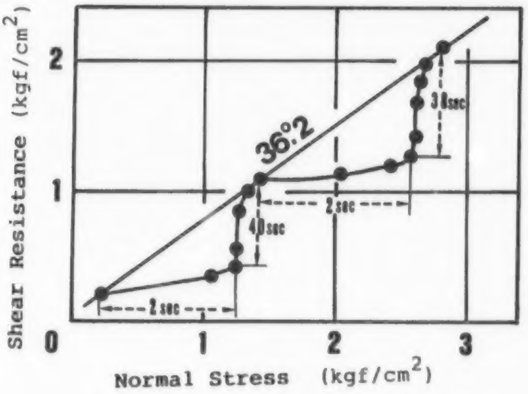


Fig. 7 Rapid Loading Test of the Saturated Denjou Torrent Deposit (Grain size: 0 - 9.5 mm, Void ratio: 0.46-0.50)

The result is Fig.6. The situation suggested in Fig.5 was reproduced in this figure, though the shear resistance line was curved around S_2 because the loading speed got slow due to limitation of air-supply capacity.
We did this test in use of various samples, a less permeable sample produced more pore pressure and took a longer time for dissipation (one day for a sample from a clayey landslide "the Jizukiyama landslide), a less saturated sample produced less pore pressure and dissipated in a shorter time (Sassa et al, 1989).

Fig. 7 is a similar test result(two steps of rapid loading were done in this test) of the saturated sample taken from the Denjou torrent deposit where the Ontake long-travelling landslide moved down over 9 km at the average speed of 20-26 m/sec. We could understand from this test result that the deposit of the Denjou torrent exerts a low apparent friction angle during a rapid loading.

When a loading is given by the loading plate in this apparatus, pore pressure is generated over the whole sample and the pore pressure will dissipate through the porous metal of both ends shown in the detailed section of the sample box in Fig.2. The drainage path in this test is about 3 cm, and it is much shorter than the real one in fields as suggested in Fig.4. Then, pore pressure dissipation in fields should be slower than that in this test.

COMPUTER SIMULATION OF LANDSLIDE MOTION

Computer simulation for flood was done by Iwasa et al, 1980, and Takahashi et al, 1986. In their research the motion of flood was dealt as a liquid having no frictional resistance and moving on a two-dimensional plane.
The author applied this method to the motion of landslide. However, the following difficulties should be overcome.

1) The motion of landslide should be on three-dimensional surface, though flood can be approximated to move on a flat two-dimensional plane.
2) The materials of landslide are rich in variety, some are very soft and very deformable, and some are hard and less deformable. "Softness" of the material should be expressed.
3) The friction between the moving mass and the unmoved ground changes with the related materials and the degree of saturation at the time. "Slipperiness" of the slope should be expressed.

Fundamental Equations for Computer Simulation

Fig.8 illustrates a moving landslide and an element-column in it, Fig.9 shows forces acting on the column. Here, the sides of column is Δx, Δy in length on the X-Y horizontal plane. We assume that the stress on vertical sides is lateral pressure only because shear forces are almost canceled each other.
The total of all forces is consumed for acceleration of the mass. Then, we obtain Equation (1)

$$a\ m = W_p + \frac{\partial P_x}{\partial x} + \frac{\partial P_y}{\partial y} + R \qquad (1)$$

Here, $W_n + N = 0$

a: Vector of acceleration, m: Mass, W_p, W_n: Components parallel/normal to slope of the weight of column (W), P_x, P_y: Components to X/Y direction of

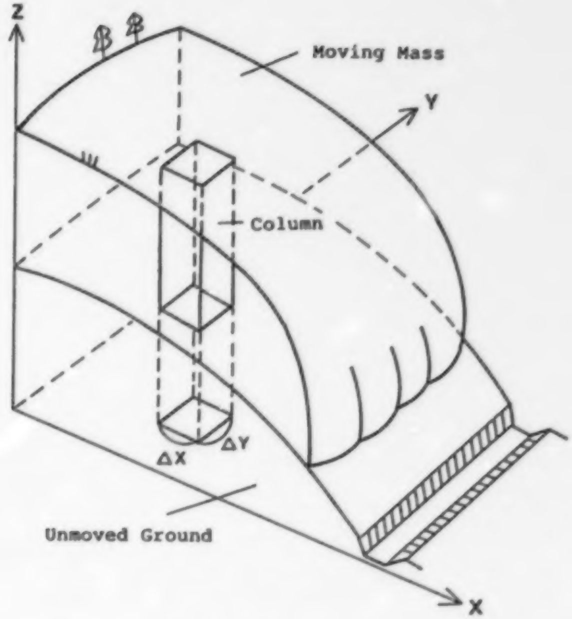


Fig. 8 A Moving Landslide and a Column in It

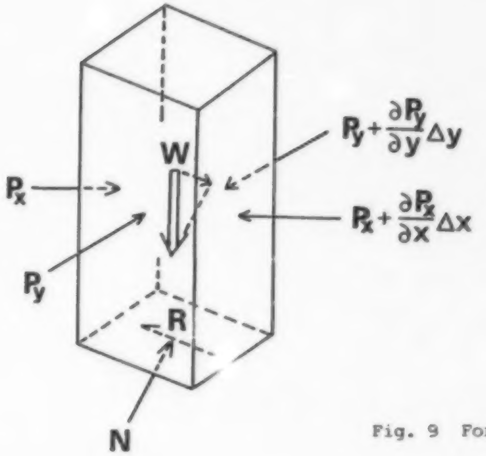


Fig. 9 Forces Acting on a Column

Application of the Computer Simulation to the Ontake Landslide

In 1984, the Ontake landslide of 36 million cubic meters was caused by the Naganoken-Seibu earthquake. The landslide mass travelled along a torrent over 9 km, and dammed up the Ohtaki river by 40 m. Fig.10 is the air photo of the Ontake landslide(the top of photo, marked by a circle) and the Ohtaki river dammed-up by the landslide mass (the bottom of photo). It was very characteristic that a part of the moving landslide mass crossed over a ridge at a curve of the Denjou torrent and entered into the neighbouring Nigori torrent(two arrows in the photo) and joined again at their confluence.
People were surprised at this long travel of a huge mass. Some researchers proposed that this mass would be transported by high air pressure like a hover-craft, some proposed that this would be a debris flow saturated by water. However, it is obvious that there was no mechanism to generate high air pressure, and there was not enough water to saturate this huge mass.

The author took a sample of the deposit from the Denjou torrent and measured the friction angle during motion and obtained 35-36.5 degrees. And he confirmed that this material exerted a low apparent friction angle during a rapid loading by the test result of Fig.7, therefore, the landslide mass can travel over the gentle torrent bed of a few degrees. According to the field investigation and the estimation of the degree of saturation, we estimated that the apparent friction (tan ϕ_a) of the well saturated part of the flowing path after the confluence of two torrents is 0.08, and the less saturated part from the landslide area to the curved point where a part of mass crossed the ridge is 0.10-0.15, and the midway beween both parts is 0.20-0.30. We estimated the lateral pressure ratio k = 0.6, which is between the dry state and the semi-liquefied state of this soil.
These values and initial position and depth of the landslide mass which was obtained from 1/5,000 map before / after the landslide were entered into the computer simulation programme, and calculated. The result of calculation well reproduced the motion of landslide crossing over the ridge and joining again at the confluence and damming up the Ohtaki river. Fig.11 is the soil distribution after deposition. The simulated maximum deposition depth was 40-60 m (the real one is also about 40 m), the total volume of deposition in the Ohtaki river was 17 million cubic meters(the real one was 19 million cubic meters).

This computer simulation could reproduce the motion of the Ontake landslide in accordance with the real phenomenon, then, it can be said that this simulation and the high speed ring shear apparatus will be utilized as a reliable method to predict the hazard area by landslides.

Finally, the author acknowledges Prof. M. Shima of Kyoto University for his advice and Mr. H. Fukuoka, a post-graduate student for his cooperation in experiments.

the lateral pressure (P), R: Shear force on the bottom of column, N: Normal force on the bottom of column

When analysing motion of numerous elements of the landslide mass, it is more convenient to calculate the motion of mass within a frame (column) fixed in the space than to trace the motion of each element. This is a method adopted in fluid dynamics. In this case, Equation (1) converted into Equation (2-1) for X-direction and Equation (2-2) for Y-direction.

$$\frac{\partial M}{\partial t} + \frac{\partial}{\partial x}(u_0\ M) + \frac{\partial}{\partial y}(v_0\ M) = gh\frac{\tan\alpha}{q+1} - kgh\frac{\partial h}{\partial x}$$

$$-\frac{g}{(q+1)^{1/2}}\cdot\frac{u_0}{(u_0^2+v_0^2+w_0^2)^{1/2}}\{\ h_c(q+1) + h\tan\phi_a\} \qquad (2\text{-}1)$$

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}(u_0\ N) + \frac{\partial}{\partial y}(v_0\ N) = gh\frac{\tan\beta}{q+1} - kgh\frac{\partial h}{\partial y}$$

$$-\frac{g}{(q+1)^{1/2}}\cdot\frac{v_0}{(u_0^2+v_0^2+w_0^2)^{1/2}}\{\ h_c(q+1) + h\tan\phi_a\} \qquad (2\text{-}2)$$

h: Depth of the moving mass, u_0, v_0, w_0: Velocity (average one on the vertical profile) to X, Y and Z-direction, M, N: Discharge in X-, Y-direction per unit width ($M=u_0h$, $N=v_0h$), k: Lateral pressure ratio, ϕ_a: Apparent friction angle on the botom of column, h_c: Cohesion head (c = $\rho g h_c$, c:cohesion, ρ:density), α, β: Inclination of the botom of column to X-axis, and Y-axis, $q = \tan^2\alpha + \tan^2\beta$

We can assume that the density of landslide mass does not change during motion, the total of mass flowing into a column is equal to the height increment of soils in the column. Then, we obtain Equation (3) which is a common equation in fluid dynamics.

$$\frac{\partial h}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0 \qquad (3)$$

These three equations are modified to difference equations for numerical computation (Sassa, 1987)
In this equation, lateral pressure ratio (k) expresses "softness" of the moving material. It is ratio of horizontal pressure/vertical pressure, the value of liquid is 1.0, the value of rigid body is 0. The usual soil is between 0 - 1.0 and expressed by Equation (4) as an extension of the Jarky equation.

$$k = 1 - \sin\phi_{ia} \qquad (4)$$

ϕ_{ia}: Apparent friction angle of a material inside the moving mass. "Slipperiness" is expressed by the apparent friction angle ϕ_a.

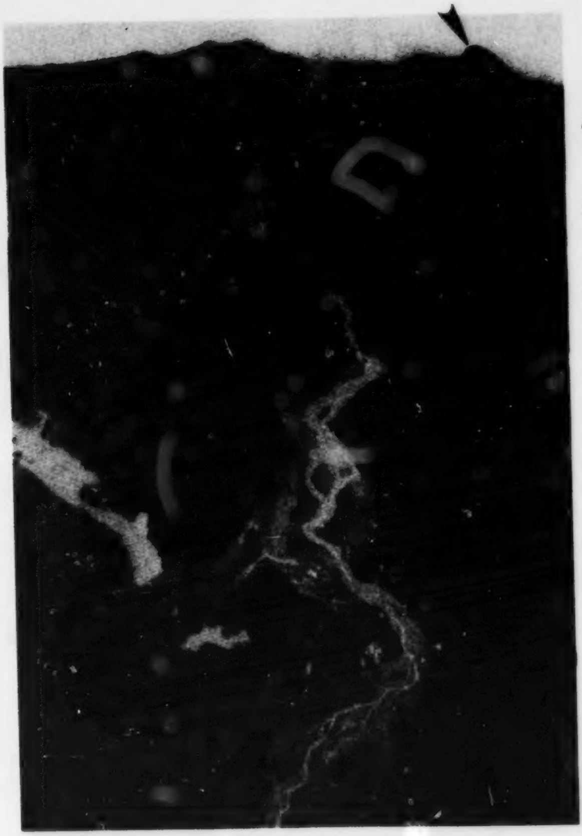


Fig. 10 The Ontake Long Travelling Landslide

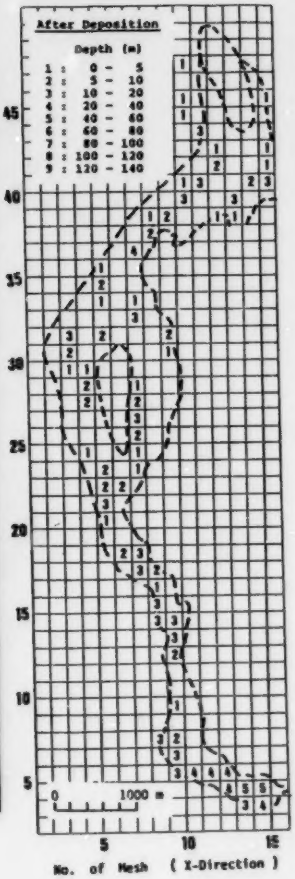


Fig. 11
Soil-Depth-Distribution after Deposition Obtained by the Computer Simulation

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LE "VIEILLISSEMENT" DES TAILLIS EN ITALIE: ETUDE AUXOMETRIQUE ET TRAITEMENT DE LA FUTAIE SUR SOUCHES

Emilio Amorini et Gianfranco Fabbio

Istituto Sperimentale per la Selvicoltura
Arezzo, Italia

FDC: 226: 222

SUMMARY

The study deals with the problem of development and stability of aged coppices and their silvicultural treatment for the conversion into high forest. The analysis of the results points out the ageing period causes no senescence crisis and functional decay up to age two or three times longer than the rotation age. The stem analysis of dominant trees proves that the increment course is composed of a series of distinct growth cycles; their importance increases with age. The meaning of these cycles is explained by the natural competition and selection process among the trees. The growth rate in the dominant storey of the aged coppice is the expression of the natural conversion to high forest. Silvicultural rules for the first period of conversion (first and second thinning) are suggested.

Key words: coppice, conversion to high forest, selection, growth.

INTRODUCTION

Les tendances récentes de la politique forestière en Italie, dirigées plus vers l'amélioration des forêts existantes que vers le développement de la surface boisée, doivent résoudre avant tout le problème du taillis. Ce type de régime concerne 3.673.800 hectares (1), c'est à dire 60% à peu près de la surface forestière, distribués dans les différents plans de végétation et milieux géographiques de la Peninsule.

Le taillis est une réalité historiquement présente, soutenue par la correspondance à la structure économique et sociale du pays jusqu'au récent passé. Tout cela, ainsi que le régime de propriété privée, prédominant dans ce type de forêt, explique le maintien prolongé du régime sur une surface si importante, au-delà de l'utilité actuelle. Si les prémisses sur lesquelles se fondait le taillis ont disparu en partie dans la dernière période, il est

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[1]Les données statistiques proviennent de l'Inventario Forestale Nazionale (1985).

évident toutefois la difficulté de dépasser le type de régime devenu caractéristique physionomique dominant du paysage forestier des Apennins et, ainsi, assimilé à "culture" du bois de feuillus.

L'actuel est ainsi un moment de transition qui voit s'opposer et toutefois coexister, dans une gamme variée de situations culturales, des choix opérationels divergents et une position d'attente forcée. Pour les mêmes espèces, parallèlement à la conservation du régime traditionel, avancent des programmes de conversion en fûtaie ou bien on assiste à la suspension, de fait, de toutes interventions sylvicoles. Cette réalité complexe s'est formée selon les exigences et les caractéristiques de la propriété.

En milieu privé, la différence croissante entre valeur du produit et fraîs d'exploitation, a conduit au mantien du régime habituel dans les situation de fertilité les meilleures et, en conditions marginales, à l'attente d'un nouvel intêret à la coupe par le prolongement de la révolution et l'accumulation du matériel sur pied. L'accroissement beaucoup plus rapide des fraîs, toutefois, a rendu souvent inéfficace l'avantage qui venait de l'adoption de révolutions plus longues, rendant économiquement négatives surfaces croissantes de taillis.

La propriété publique au contraire a d'abord avancé la solution du changement de régime dans certaines forêts et ensuite favorisé plus diffusément la conversion en futaie. En situation de marginalité culturale le choix a été résolu par la mise au repos des peuplements, dans la perspective de rejoindre par vieillissement une amélioration progressive et le lent rééquilibre de la structure vers l'état naturel de futaie.

La constitution progressive de noyaux, même importants, de futaies sur souches et l'élargissement contemporain de l'aire en évolution naturelle ont stimulé la discussion sur l'opportunité et sur la validité des choix alternatifs entrepris (Clauser 1975, Giannini et al. 1976, Hippoliti 1978, Bernetti 1980, Bagnaresi 1981, Benassi 1981, Susmel 1981, Eccher et al. 1983). On a avancé des doutes sur la stabilité des peuplements en conversion (futaie sur souches) et des préoccupations sur la sénescence précoce et sur la probable crise de la structure du taillis en viellissement.

En définitif, même en l'absence de perspectives valables de contenir dans le futur immédiat la crise du taillis, on a mis en discussion les bases biologiques du changement de régime. Dans cette situation l'Istituto Sperimentale per la Selvicoltura a entrepris, au début des années 70, l'étude des taillis en évolution naturelle par vieillissement et, en parallèle, des taillis en conversion, pour acquérir des éléments de connaissance sur le développement de ces peuplements, à mettre à l'appui des futurs choix sylviculturaux.

MATERIELS ET METHODES

L'étude a concerné des peuplements typiques de l'étage moyen et supérieur des Apennins, c'est à dire des taillis simples et avec réserve, à prédominance de chêne chevelu et de hêtre.

Les placettes expérimentales sont situées dans l'Italie centre-septentrionale (Emilia-Romagna, Toscana et Umbria) à une altitude comprise entre 700 et 1300 m. Le substratum géologique comprend, de Nord à Sud, des formations arénacées, calcaires-argilleuses ou simplement calcaires. Le régime pluviométrique est de type subméditerranéen montagneux; les précipitations annuelles atteignent 1000 à 1450 mm; la température annuelle moyenne est de 8 à 13°C.

L'étude a été conduite soit sur des placettes permanentes articulées sur différentes thèses, soit sur des parcelles semipermanentes qui ont permis d'étendre l'examen, avec des relevés ponctuels, à des structures et des typologies différentes. Au tableau 1 on a rapporté les caractéristiques dendrométriques de deux placettes expérimentales qui décrivent la typologie dominante des taillis étudiés.

Taillis à prédominance de chêne chevelu: le peuplement, âgé de 20 ans (en 1972, année du début de l'essai) présentait de bonnes conditions de fertilité (attribuées aux niveaux supérieurs prévus dans les tables de production). Les réserves étaient peu nombreuses (jeunes et avec un développement égal à celui des meilleurs rejets), la densité du couvert ainsi que le nombre de souches etaient élevés. La composition spécifique était dominée par le chêne chevelu et le charme houblon, avec participation secondaire de frêne à fleur, d'érable à feuilles d'obier et d'érable champêtre. L'âge minimum d'exploitabilité antérieurement prévu était 10 ans, ensuite 14 ans. Dans les peuplements du domaine forestier l'âge d'exploitabilité habituel était de quelques années supérieur. Le dernier recépage avait été pratiqué en 1952-53.

Taillis pur de hêtre: le peuplement, âgé de 27 ans (en 1972, au début de l'étude), en bonnes conditions de fertilité, était caractérisé par la présence de quelques grandes souches, aux nombreux brins avec un large couvert vertical au sol; la fréquence majeure de souches toutefois présentait un nombre réduit de rejets. Peu de réserves de grandes dimensions (à peu près 10 par hectare, âgées presque de 100 ans) conditionnaient le développement des brins des cépées environnantes.

Le hêtre était presque exclusif; quelques tiges de chêne chevelu et de merisier témoignaient une composition spécifique plus riche dans le passé. L'âge minimum d'exploitabilité antérieurement prévue était 22 ans; l'habituel était, même dans ce cas, de quelques années supérieur.

Le protocole expérimental prévoit deux niveaux de recherche: contrôle de l'évolution du taillis en absence de traitement et après éclaircie (2); analyse des différentes modalités de constitution et de gestion de la futaie

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[2] La technique employée pour la conversion se rapporte à la méthode de "l'éclaircie d'élevage à la futaie" (Amorini, Fabbio 1986) qui a été mise au point à travers son application pratique dans les taillis des Apennins. Il s'agit d'une méthode qui favorise la première phase du traitement par une éclaircie, par le bas ou mixte, effectuée sur les souches, qui sélectionne les meilleurs rejets (baliveaux) dans un peuplement monoplan, à densité suffisamment élevée (1500-2500 arbres par hectare). On conduit cette première intervention normalement à un âge supérieur (en général de 1/4 à 1/2) à celui

sur souches (âge d'éxécution, type et intensité de l'éclaircie d'élevage à la futaie, type, intensité et rotation des éclaircies suivantes).

Tableau 1: Caractéristiques dendrométriques des parcelles expérimentales au cours des inventaires successifs. Données par hectare.

C H E N E C H E V E L U

Taillis en evolution naturelle

Age	Souches N°	Rejects N°	Reserves N°	G m^2	d_{dom} cm	h_{dom} m	V m^3	Im_v m^3
20 (1972)	3254	8276	40	24,2	14,5	12,2	107,1	5,4
32 (1984)	2554	5376	40	30,0	19,9	20,3	210,0	6,6

Futaie sur souches

Age	Baliveaux N°	G m^2	d_{dom} cm	h_{dom} m	Volume m^3 Mat.s.pied	Prod.int.	tot.	Im_v m^3
20 (1972)	1048	12,4	14,9	12,4	59,7	52,0	111,7	5,6
32 (1984)	1040	26,6	21,4	20,1	199,9		251,9	7,8
32 (1984)	792	17,0			131,6	68,3		

H E T R E

Taillis en evolution naturelle

Age	Souches N°	Rejects N°	Reserves N°	G m^2	$d_{\bar{g}}$ cm	$h_{\bar{g}}$ m	V m^3	Im_v m^3
27 (1972)	1160	7508	10	27,4	6,7	5,4	163,2	6,0
37 (1982)	936	6836	10	36,8	8,3	11,1	246,6	6,5
42 (1987)	880	5624	10	39,0	9,4			

Futaie sur souches

Age	Baliveaux N°	G m^2	$d_{\bar{g}}$ cm	$h_{\bar{g}}$ m	Volume m^3 Mat.s.pied	Prod.int.	tot.	Im_v m^3
27 (1972)	2214	18,0	9,6		110,5	61,6	172,1	6,4
37 (1982)	2174	27,8	12,8		201,8		263,4	7,1
42 (1987)	2096	32,9	14,1					
42 (1987)	706	19,6	18,8					

Pour les futaies sur souches: 1972 = Situation après l'éclaircie d'élevage à la futaie.
1984 Chene = Situation avant et après la deuxième éclaircie.
1987 Hêtre = Situation avant et après la deuxième éclaircie.

L'étude a prévu plusieurs phases avec emploi de méthodologies différentes:

- inventaires périodiques des paramètres dendrométriques (nombre de souches et de rejets, surface terrière, hauteur moyenne et dominante, volume, accroissement en volume), pour fixer les stades successifs de développement de la structure;
- examen de la distribution des grandeurs relevées (fréquences des brins et

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habituel d'exploitabilité. On perfectionne la structure en futaie sur souches par une deuxième éclaircie sélective après 10-15 ans. Les deux interventions se complètent pour atteindre, de fait, le changement de régime. La phase suivante du traitement de conversion prévoit deux-trois éclaircies sélectives jusqu'aux coupes de régéneration.

valeurs de la surface terrière par classes de diamètre, par espèces, par classes sociales), pour connaître en détail les mécanismes du développement du peuplement;

- transect de structure avec relevé des variations de la composition spécifique et du rang social des individus, pour suivre physionomiquement le dynamisme du peuplement;
- analyse de la tige conduite sur un échantillon stratifié de brins, de position sociale connue, pour mettre en évidence le processus de la compétition, le début et la progression de la hiérarchisation sociale.

RESULTATS

T a i l l i s e n V i e i l l i s s e m e n t

Les taillis en évolution naturelle, dans l'intervalle considéré jusqu'à un âge presque double de l'âge habituel d'exploitabilité, ont mis en évidence des changements importants de la structure. L'évolution du peuplement s'est traduite en compétition interindividuelle importante; le résultat de la pression de la sélection naturelle a été la mort d'entières cépées et la forte réduction du nombre de rejets.

La recomposition de la structure s'est déroulée à rythme différent dans les deux typologies examinées. Dans le taillis à dominance de chêne chevelu les souches se sont réduites de 1/5 et le nombre de brins de 1/3 environ; dans le taillis de hêtre la mortalité a été plus faible et a éliminé, dans un laps de temps plus long, 1/4 des rejets.

Le dynamisme évolutif de ces peuplements est témoigné par l'évolution des paramètres auxométriques au cours des inventaires successifs (tableau 1). Malgré l'importante mortalité naturelle, la surface terrière a enregistré un accroissement soutenu et a atteint le seuil de 30 et 39 m^2 par hectare, dans les taillis de chêne chevelu et de hêtre. La hauteur dominante à l'âge actuel est presque de 20 m; dans le chêne chevelu la hauteur des tiges dominantes a présenté une augmentation de 8 m environ dans les dernières 12 années; l'accroissement moyen annuel n'a pas encore atteint sa culmination.

Le matériel sur pied a fortement augmenté dans les deux typologies; il est quasi le double dans le taillis de chêne chevelu et a eu un accroissement de plus de 80 m^3 en 10 ans dans le taillis de hêtre. L'accroissement moyen annuel du volume, qui résume la progression des différents indicateurs dendrométriques, est encore croissant dans les deux peuplements, jusqu'aux dernières années observées. La différence entre accroissement courant et accroissement moyen annuel montre une culmination non proche de ce dernier dans le peuplement de chêne chevelu, tandis que dans le taillis de hêtre la valeur de l'accroissement moyen annuel, qui grandit plus lentement, indique une phase d'accroissement positive mais de réalisation plus graduelle.

La distribution du nombre des rejets dans le taillis de chêne chevelu à l'âge de 32 ans, met en évidence la transformation qui est en train de se

passer (mortalité dans les classes inférieures, formation d'une deuxième classe modale) et permet d'interpréter l'évolution d'ensemble des fréquences comme la superposition de deux distinctes distributions: la première de type encore fortement asymptotique déterminée surtout par le charme et par les espèces secondaires, la deuxième de type gaussien constituée principalement par le chêne chevelu (figure 1).

La composante plus dynamique du peuplement tend à la futaie presque équienne. L'examen de la distribution en surface terrière enregistre l'importance du changement ayant eu lieu dans le taillis. Exemple: les rejets présents au-delà du seuil diamétrique de 9 cm ont augmenté, en 12 ans, jusqu'à peu près 1000 par hectare et représentent 1/5 du peuplement tandis que leur "poids" en surface terrière égale presque 60% du total. Les 300 tiges de diamètre supérieur à 14 cm constituent un peu plus que 5% du peuplement, mais presque 1/3 de la surface terrière d'ensemble.

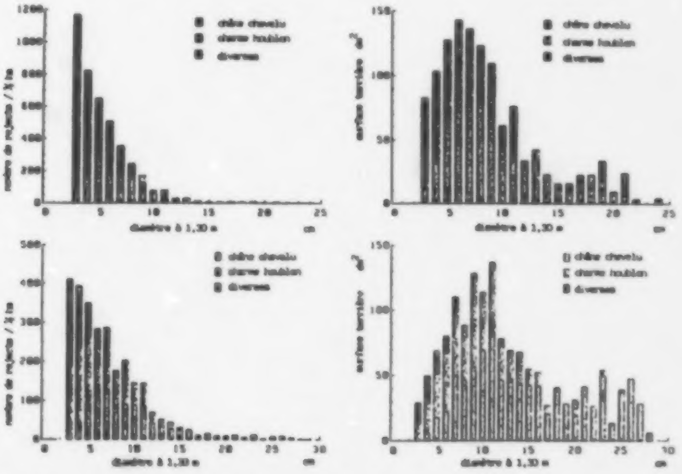

Figure 1: Répartition du nombre de rejets et de la surface terrière par classes de diamètre dans le taillis de chêne chevelu, à 20 et 32 ans.

La consistance et le dynamisme des presque 1000 brins par hectare de diamètre supérieur à 9 cm suggèrent l'hypothèse d'une sous-population, relativement autonome, en mesure de se développer à des rythmes propres au regard du reste du peuplement qui semble toujours plus interpréter un rôle complémentaire. Ces 1000 rejets montrent d'être la futaie en formation, en tant que peuplement spontanément exprimé par le taillis en évolution naturelle. En ce qui concerne l'espèce et la fertilité étudiées, l'âge de 32 ans permet d'individuer ce noyau de futaie déjà dans la résolution graphique des grandeurs dendrométriques relevées.

L e s F u t a i e s s u r S o u c h e s

Les futaies sur souches constituées par l'éclaircie d'élevage à la futaie avec 1500-2500 baliveaux par hectare, ont été éclaircies une deuxième fois après 12-15 ans (tableau 1).

La première intervention, qui a prélevé 46% et 36% du matériel sur pied (chêne chevelu et hêtre), a pris le caractère d'une éclaircie de moyenne-forte intensité. Les deux typologies après l'éclaircie résultaient des structures de type monoplan et à bonne densité.

La futaie sur souches de chêne chevelu présentait 1848 baliveaux, une surface terrière de 12,4 m^2 et un volume de 59,7 m^3 par hectare; le peuplement de hêtre était constitué par 2214 baliveaux, avec une surface terrière de 16,0 m^2 et un volume de 110,5 m^3 par hectare. La futaie sur souches de chêne chevelu, après 12 ans avait acquis de nouveau la fermeture des cimes et présentait une diffuse codominance et des individus en phase récessive de l'étage principal. La mortalité en cette période a été négligeable, par conséquence la densité résultait presque inchangée, la surface terrière avait plus que doublé la valeur à 20 ans et le volume du matériel sur pied était arrivé à 200 m^3 par hectare environ, augmentant plus que trois fois sa valeur initiale.

La futaie sur souches de hêtre, 15 ans après la première éclaircie, avait déjà refermé le couvert, réarticulé la structure de l'étage principal et constitué un niveau inférieur d'individus dominés. Dans cette période la densité s'était réduite de 5% environ tandis que la surface terrière avait atteint 32,9 m^2 par hectare à 42 ans, valeur double de celle delivrée à la première éclaircie. Le volume du matériel sur pied (à l'âge de 37 ans) a depassé 200 m^3 par hectare, avec un accroissement de 90,0 m^3 environ en 10 ans.

L'accroissement moyen du volume sur pied a répondu positivement à la première éclaircie rejoignant, dans les deux peuplements, des valeurs supérieures à celles du taillis non traité, au même âge. Dans la futaie de chêne chevelu le paramètre est passé de 5,6 à 7,8 m^3 , dans celles de hêtre de 6,4 à 7,1 m^3, ce qui indique la postposition ultérieure de la culmination par rapport au taillis en évolution naturelle.

La deuxième intervention, 12 à 15 ans après l'éclaircie d'élevage à la futaie, aussi bien dans le peuplement de chêne chevelu que de hêtre, conclut la première phase du traitement de conversion, la plus délicate, qui change la physionomie du peuplement en structure de futaie. L'intervention effectuée, de type sélectif, a remarquablement pesé sur la densité éliminant 2/3 des baliveaux dans le chêne chevelu (66%) et plus de la moitié dans le hêtre (57%); elle a pesé moins lourdement sur le matériel sur pied, en tant qu'éclaircie de moyenne-forte intensité, enlevant un peu plus d'un tiers de la surface terrière présente dans les deux peuplements (36 et 40%).

Après l'intervention dans la futaie sur souches de chêne chevelu, 792 tiges étaient présentes avec 17,0 m^2 de surface terrière et 132 m^3 de peuplement principal par hectare; le diamètre moyen est augmenté de 13,6 à 16,5 cm. La futaie de hêtre était constituée par 708 tiges; la surface terrière par hectare égalait 19,6 m2; le diamètre moyen était passé de 14,1

à 18,8 cm.

Dans l'application culturale l'éclaircie a individué parmi les tiges choisies un certain nombre (de 200 à 300 par hectare) des phénotypes valables (correcte implantation sur la souche, tige droite, houppier équilibré) sur lesquels on pourra baser les interventions successives. Cependant, leur rôle, quand-même comparable aux arbres d'avenir du traitement de la futaie équienne ou du balivage des taillis, ici est surtout cultural. Les taillis en conversion des Apennins, d'ancienne surexploitation sylvicole et relativement jeunes, ont besoin en premier lieu de se développer dans leur ensemble pour acquérir hauteur et volume sur pied; une densité suffisante permet le maintien du micro-climat intérieur nécessaire au développement des processus de reconstitution biologique. L'éclaircie donc, même en individuant utilement des points de repères dans le peuplement, doit encore favoriser la promotion massale des arbres restants.

L'analyse de la tige des brins échantillonnés a confirmé l'allure d'accroissement des placettes d'origine et a consenti de décrire les processus de croissance des catégories sociales désignées et la constitution de relations interindividuelles jusqu'à un âge presque double de celui d'exploitabilité du taillis. Les arbres examinés appartiennent à l'étage dominant. Dans le taillis en évolution naturelle, ceux-ci représentent les individus (en nombre minoritaire) qui constituent, aux termes réels, la fraction motrice du peuplement; dans la futaie sur souches au contraire ils représentent la presque totalité des tiges présentes.

Les arbres choisis ont donc échantillonné les dendrotypes homologues dans les deux situations, traitement sylvicole et absence de traitement. Les analyses de la tige indiquent que le trend de développement est formé par plusieurs cycles, d'importance et de durée croissantes jusqu'aux derniers âges étudiés, marqués par d'ultérieures culminations relatives et composés par des phases consécutives de reprise et de rallentissement de l'accroissement. Cette allure est individuée par l'accroissement courant en volume (figure 2), qui résume les variations du rythme de croissance de tout l'individu.

Dans le taillis en évolution naturelle les rejets dominants mettent en évidence, après l'âge habituel d'exploitation du taillis (14 ans dans le taillis de chêne chevelu et 24 dans celui de hêtre), tout d'abord le maintien et ensuite l'augmentation de l'accroissement courant en volume. Telle allure est expliquée par les reprises de croissance en diamètre et par l'accroissement en hauteur toujours soutenu. Aux dernières années observées les brins dominants expriment les valeurs maximum du rythme de développement de leur vie entière, indices d'une phase d'accroissement encore juvénile.

Les cycles de développement individués doivent être considérés le résultat de l'évolution de la sélection interindividuelle qui se déroule en phases successives de croissance libre, suivies par des périodes de forte compétition. A la fin de chaque cycle le rejet confirme le rang social dominant ou bien regresse progressivement de l'étage principal (figure 3).

Tandis que les premiers cycles, de brève durée et d'intensité limitée, confirment en peu d'années la hiérarchie sociale à l'intérieur de la cépée, les successifs, plus soutenus et importants, déterminés par l'apparition et ensuite par la prédominance des rapports entre les rejets des souches

limitrophes, commencent à marquer la différenciation sociale dans l'étage dominant du taillis en évolution naturelle.

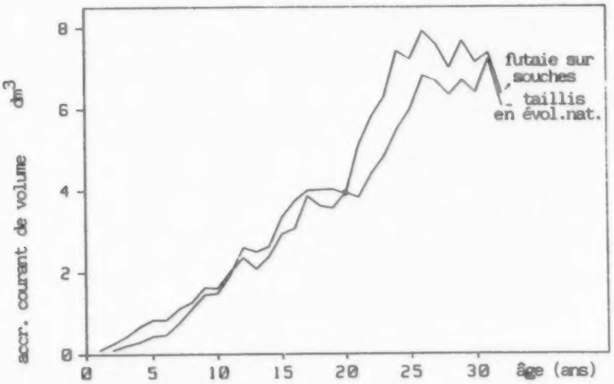

Figure 2: Allure de l'accroissement courant de volume des rejects dominants du taillis et de la futaie sur souches de chêne chevelu, jusqu'à l'âge de 32 ans.

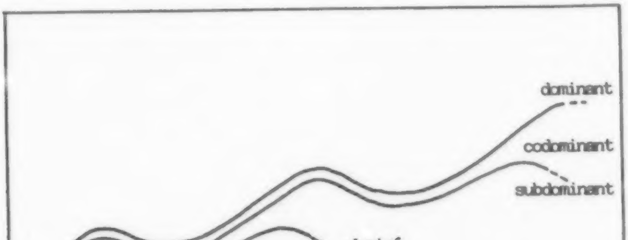

Figure 3: Schéma des processus de sélection, par cycles successifs, dans l'étage dominant du taillis en évolution naturelle.

La détermination de ces dernières phases de développement des brins dominants et leur valeur, supérieure par rapport à l'accroissement passé, répondent fondamentalement aux questions posées au début de l'étude. Il existe

dans le taillis, même après l'âge proprement dit de "maturité" des processus spontanés de développement positif. On peut déterminer les phases optimales pour l'application du traitement sylvicole dans le but de favoriser ce trend positif.

L'analyse des arbres échantillonnés dans la futaie sur souches confirme cette interprétation des données. L'éclaircie a provoqué une augmentation du rythme de croissance mais n'a pas changé l'allure de l'accroissement courant en volume qui répète, sur des valeurs plus élevées, celui des rejets dominants du taillis, en anticipant l'âge de culmination.

En définitif l'ensemble des données confirme que le traitement de conversion seconde la reprise spontanée du taillis en évolution naturelle et la soutient. Les éclaircies mettent en évidence ce qui existe déjà dans le taillis, le valorisent et l'accroissent.

CONCLUSIONS

L'étude conduite a répondu à certaines questions liées à la présence et à la nécessité d'aménagement de vastes superficies de taillis en vieillissement et a fourni des indications sylvicoles pour le traitement de conversion. La conversion par voie naturelle est en effet la solution culturale praticable pour la fraction de taillis qui n'est plus expolitée à cause de l'importante réduction du marché du bois de chauffage, et susceptible en plus d'amélioration.

L'allure de l'accroissement des taillis en évolution naturelle a mis en évidence des processus positifs de croissance qui démontrent sans fondement l'hypothèse de "vieillissement, sénéscence et dépérissement structural", prévisibles peu après l'âge habituel d'exploitabilité. La mortalité des rejets, des cépées entières et l'impression conséquente de désordre structural, ont consolidé cette opinion de décadence physiologique lorsque, au contraire, cela doit être considéré plutôt l'expression d'une recomposition de la structure et de la vitalité biologique du peuplement.

La constatation de la reprise naturelle de l'accroissement et son importance, projetant à long terme, stabilité et productivité de ces peuplements, prouvent l'existence de bases biologiques pour la conversion des taillis.

L'allure de l'accroissement des rejets dominants pendant les derniers cycles de développement indique leur transformation progressive en protagonistes principaux de la lente acquisition de l'état de futaie par vieillissement. L'acquisition individuelle des capacités croissantes de production représente le résultat probable du passage graduel du rejet, de composant entre-autre de la souche, à individu physiologiquement autonome. L'abandon progressif du système racinaire primitif est documenté par les premières études sur l'appareil radical d'arbres de futaie sur souches (Amorini, Fabbio 1990); la création graduelle d'un nouveau système racinaire, fonctionel à la biomasse acquise à des âges supérieurs à celui d'exploitabilité habituel, semble confirmer l'acquisition d'autonomie et expliquer les rythmes d'accroissement exprimés.

Cette dernière observation expérimentale s'explique par l'équilibre qui doit s'établir naturellement entre biomasse aérienne et biomasse racinaire (Clauser 1981) lorsque, la première n'étant plus annulée par le recepage, l'autre continue à augmenter au-delà des valeurs précédemment fixées par la coupe et jamais auparavant dépassées.

L'éclaircie d'élevage à la futaie, effectuée à un âge de 1/4 à 1/2 supérieur à l'âge d'exploitabilité habituel, se place utilement dans le trend de développement positif exprimé par le taillis dans la même période. L'éclaircie d'élevage à la futaie et l'éclaircie successive, après 10-15 ans. mettent en évidence la futaie en formation cachée dans le taillis.

Sur taillis de moyenne-bonne fertilité, les deux premières interventions du traitement de conversion doivent être effectuées avec critère sélectif et intensité soutenue; celles-ci modèlent, avant 30-50 ans, le taillis en structure de futaie et complètent la première phase du traitement de conversion, formant des peuplements à aménager avec des règles culturales analogues à celles appliquées à des futaies issues de graines, de la même espèce et du même stade de développement.

Les rythmes importants de croissance après l'éclaircie d'élevage à la futaie et les produits intermédiaires exploités, cnduisent à considérer sans fondement le caractère provisoire de la futaie sur souches, en analogie à ce qu'on a constaté pour le taillis. On avance donc la possibilité de conduire dans les taillis en conversion une sylviculture active, dynamique et non seulement de pure attente de la future régénération naturelle.

En définitif le traitement de conversion de taillis (simples ou avec peu de réserves) en futaie sur souches ne se fonde pas sur des intentions génériques d'amélioration sans aucun objectif cultural défini mais, au contraire, sur la capacité du taillis d'exprimer des processus biologiques positifs.

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Le 25 janvier 1990

A V A N T A G E S D ' U N E S Y L V I C U L T U R E D Y N A M I Q U E P O U R L E D O U G L A S E N F R A N C E

Jean De Champs[1]

Directeur Région Centre-Ouest de l'Association Forêt-Cellulose (AFOCEL)
Les Vaseix
87430 - Verneuil/sur/Vienne - France

FDC: 242: 174.7 Pseudotsuga menziesii Franco: (44)

RESUME

On décrit 6 essais de 1ère éclaircie précoce sur Douglas, mis en place en France entre 1981 et 1986 ; tous comportent au moins 1 témoin et 1 traitement retirant 1 ligne sur 3 + 1 arbre sur 4. Les résultats 1989 montrent que la perte de production, parfois sévère, est très temporaire ; l'effet sur la croissance en diamètre est important, y compris sur les dominants ; la stabilité est améliorée. On termine sur les problèmes de qualité du bois, plus ou moins liée à la largeur des cernes ; la sylviculture la plus dynamique ne permet jamais de retrouver des cernes aussi larges qu'avant la fermeture du peuplement. La qualité du bois dépend aussi de son homogénéité intra-cerne et de l'absence de noeuds.

Mots-clés : Douglas, sylviculture, éclaircie, stabilité, largeur de cernes.

SUMMARY

Title: Advantages of a dynamic silviculture for Douglas-fir in France

The author describes six early first thinning trials in Douglas-fir plantations conducted in France beetween 1981 and 1986. They all include at least one control and one treatment in which each third line plus each fourth tree in the remaining lines is removed. The results observed in 1989 show that the loss of production, which is sometimes high, is very limited in time. The effect on diameter growth is important, also on dominant trees ; stability is improved. Problem of wood quality is then discussed ; it is more or less related to ring width ; the most dynamical silviculture is unable to produce rings as wide as they were before crown closure. The wood quality also depends on intra-ring homogeneity and on the absence of knots.

Key-words: Douglas-fir, silviculture, thinning, stability, ring-width.

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INTRODUCTION : LE DOUGLAS EN FRANCE

Historique et importance

Le Douglas (Pseudotsuga menziesii Franco) a été introduit en 1842 ; mais jusque vers 1930, il ne s'agissait guère que d'arbres de parc, d'arboreta, ou de toutes petites plantations. Puis, quelques "pionniers" tentèrent les premiers vrais reboisements, notamment dans le Beaujolais, en Normandie, et en Limousin. Il fallut cependant attendre la création du Fonds Forestier National (F.F.N.) en 1946 pour que les plantations se développent, surtout à partir des années 1960. Puis, devant les excellents résultats obtenus, les reboiseurs Français l'utilisèrent de plus en plus, au point qu'aujourd'hui le Douglas a pris le premier rang dans le cadre du F.F.N., avec 25 à 26 % des surfaces reboisées annuellement en France, et avec des pointes supérieures à 60 % dans certaines régions et pour certaines années.

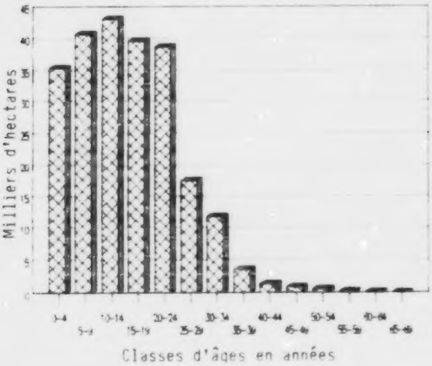

Figure 1: Surfaces 1987
(Areas 1987)

Cela dit, le massif du Douglas ne représente encore qu'une surface modeste, évaluée à 233 000 hectares en 1987 ; et cette forêt est encore très jeune, comme on peut le constater sur la figure 1 ci-contre, qui donne les surfaces par classes d'âge. En tous les cas, il ne fait pas de doute que l'engouement pour le Douglas en France n'est pas une mode, et que cette espèce est appelée à se développer encore beaucoup.

Les reboisements

Les premiers reboisements ont manifestement été réalisés avec une certaine méconnaissance de l'écologie de l'espèce : plantations trop denses (2 à 3000, voire 3500 plants/hectare), faites parfois sous abri, avec un matériel végétal quelconque, qu'il s'agisse de la provenance ou de la qualité du plant, bien entendu sans travail du sol, ni fertilisation, et probablement des entretiens trop sommaires.

Depuis, les techniques ont beaucoup évolué, avec une forte réduction des densités de plantation (ramenées vers 1000/hectare), des provenances connues et testées en France (surtout Washington, altitude inférieure à 500 m), des plants de qualité, mis en place sur terrain travaillé et ayant reçu une fertilisation phosphatée. Enfin, on connait mieux les besoins de l'espèce en lumière et en espace, ce qui se traduit par des entretiens plus soignés, et conduits plus longtemps.

La sylviculture

Celle-ci a aussi beaucoup évolué : dans les années 1960/75, on ne procédait guère qu'à des éclaircies trop tardives et très légères, n'enlevant que 15 à 20 % des tiges, parfois sans même cloisonner ; on en arrive aujourd'hui à des éclaircies précoces, avec cloisonnements denses, accompagnés d'une éclaircie sélective, et on enlève couramment 40 à 50 % des tiges. Une 2ème éclaircie est réalisée 5 à 8 ans après la 1ère, et on peut prévoir la coupe rase dès 35/40 ans, avec des volumes unitaires d'environ 1,5 m3. De plus l'élagage artificiel, pratiqué sur 6 mètres de hauteur et 250 tiges/hectare, commence à se développer.

La présente communication se propose de présenter quelques résultats d'essais d'éclaircie et de montrer l'intérêt d'une sylviculture très dynamique pour le Douglas.

METHODES

Description des essais d'éclaircie

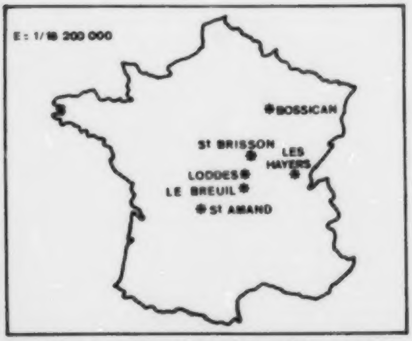

Figure 2: Localisation des essais (Trials localization)

Nous utiliserons les résultats de 6 essais, dont on trouvera la localisation sur la carte ci-contre (figure 2), et l'état juste avant la 1ère éclaircie dans le tableau 1 ; par ailleurs, le tableau 2 donne la description des traitements testés lors de la 1ère éclaircie.

On remarquera que le traitement 5, présent dans 4 essais, peut être qualifié de sylviculture extrême, dans la mesure où on enlève, dès la 1ère éclaircie, 67 % des tiges. Par ailleurs, 2 traitements (1 = témoin, et 4) sont présents dans les 6 essais.

Tableau 1: Etat des peuplements avant la 1ère éclaircie[2]
(Stands before first thinning)

	Année	Age	Ho	Table	Classe	N	S %	Hg	Dg	E
LODDES	1981	18	13,56	NE	II-	1701	19,2	12,04	16,25	74
LE BREUIL	1986	20	13,96	NE	III+	1154	22,7	12,76	18,20	70
BOSSICAN	1984	17	n.m.	NE	II-	1069	-	n.m.	16,88	-
LES HAYERS	1983	20	14,23	NE	II-	1246	21,4	13,37	15,95	84
ST BRISSON	1984	18	10,78	NE	III-	1083	30,3	10,24	18,40	56
ST AMAND	1984	19	14,70	O	II+	1279	20,4	13,54	16,41	83

n.m. = non mesurées en 1984 : Ho = 15,77 en 1989
NE = Nord-Est du Massif-Central, O = Ouest du Massif-Central
II- = fertilité inférieure à la classe II (+ = supérieure)

Fig. 3: St Amand 1984, Trait. 4

Fig. 4: Mêmes arbres, en 1989
(Same trees in 1989)

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[2] Toutes les données fournies ici et ultérieurement sont ramenées à l'hectare ; symboles et unités sont les suivants :

Age : en années depuis la graine
Ho : en mètres : hauteur dominante (100 plus gros à l'hectare)
N : nombre de tiges vivantes par hectare
S % : facteur d'espacement de Hart-Becking
Hg : en mètres : hauteur de l'arbre de surface terrière moyenne
Dg : en centimètres : diamètre de l'arbre de surface terrière moyenne
D : " " : " " " moyen (moyenne arithmétique)
E : rapport Hg/Dg : élancement
G : en mètres-carrés : surface terrière à l'hectare
V : en mètres-cubes : volume bois fort à l'hectare
Lc : en millimètres : largeur de cerne
I : accroissements (IH, ID, IG, IV...)
100 (ou 200, ou 300), après les symboles précédents : concerne les 100 (ou 200, ou 300) plus gros arbres à l'hectare (en 1989).
Mv : en kilos/mètre-cube : masse volumique

Tableau 2 : Traitements testés en 1ère éclaircie
(Treatments of first thinning)

N° traitement:	1	2	3	4	5
Abréviation:	T	EL 1/5 + S	EL 1/3	EL 1/3 + S 1/4	EL 1/3 + S 1/2
Description en clair:	Témoin non éclairci	Eclaircie en lignes (1 sur 5) + sélective (*)	Eclaircie en lignes (1 sur 3)	Eclaircie en lignes (1 sur 3) + sélective (1 sur 4)	Eclaircie en lignes (1 sur 3) + sélective (1 sur 2)
Total (%) enlevé en éclaircie	0	46 % ou 54 %	33 %	50 %	67 %
LODDES	X	X	X	X	
LE BREUIL	X			X	X
BOSSICAN	X		X	X	X
LES HAYERS	X		X	X	X
ST BRISSON	X		X	X	X
ST AMAND	X	X		X	

(*) 32 % du peuplement après cloisonnement à LODDES, 43 % à ST AMAND, soit respectivement 26 et 34 % du peuplement total, avant cloisonnement.

Le tableau 3 (à la page suivante), donne, par traitement et par essai, les principales caractéristiques des peuplements avant et après la 1ère éclaircie, ainsi que le nombre de répétitions (blocs) de chaque essai.

Seul l'essai de LODDES a fait l'objet d'une 2ème éclaircie, 5 ans après la 1ère ; pour les 4 traitements, il s'agissait d'une éclaircie sélective ; en ce qui concerne les témoins, on a simplement enlevé les Douglas morts.

Mesures effectuées

Les mesures portent sur une surface de l'ordre de 10 ares par parcelle unitaire, entourée d'une bande de protection d'environ 10 mètres. Elles ont été les suivantes, au moment de la 1ère éclaircie :

Avant éclaircie:
- mesure surface zone mesurée
- repérage hauteur 1 m 30
- inventaire en circonférence
- martelage selon protocole

Eclaircie:
- établissement d'un tarif de cubage
- mesure hauteurs sur arbres abattus

Après éclaircie:
- repérage sur plan carroyé des arbres exploités

Un nouvel inventaire a été fait 2 ou 3 ans après l'éclaircie, sauf à ST BRISSON. Pour LODDES, on a fait les mêmes mesures que ci-dessus, à la 2ème éclaircie, fin 1986. Toutes les parcelles ont été inventoriées à la fin 1989.

Tableau 3: Principales données avant et après la 1ère éclaircie
(Main data before and after first thinning)

Traitements		1		2		3		4		5	
AV/AP écl.		AV	AP	AV	AP	AV	AP	AV	AP	AV	AP
	N	1743	1743	1732	937	1636	1092	1703	845	-	-
LODDES	D	16,08	16,08	16,03	17,01	16,53	16,44	16,32	17,25	-	-
(2 blocs)	G	35,38	35,38	34,95	21,29	35,11	23,18	35,60	19,73	-	-
	V	200,9	200,9	198,0	122,8	201,3	132,7	203,2	114,7	-	-
	N	1171	1171	-	-	-	-	1108	532	1182	419
LE BREUIL	D	17,60	17,60	-	-	-	-	18,95	19,13	18,11	19,49
(1 bloc)	G	28,49	28,49	-	-	-	-	31,22	15,28	30,45	12,51
	V	166,7	166,7	-	-	-	-	187,3	91,9	180,1	75,7
	N	1065	1065	-	-	1080	720	1092	548	1041	378
BOSSICAN	D	16,98	16,98	-	-	16,75	16,75	16,60	17,00	17,18	17,95
(3 blocs)	G	24,11	24,11	-	-	23,81	15,87	23,64	12,44	24,12	9,57
	V	130,0	130,0	-	-	128,4	85,6	127,5	67,7	130,1	52,5
	N	1211	1211	-	-	1233	813	1257	609	1282	477
LES HAYERS	D	16,01	16,01	-	-	15,84	16,04	16,13	17,33	15,80	17,52
(3 blocs)	G	24,38	24,38	-	-	24,30	16,42	25,68	14,37	25,13	11,50
	V	153,5	153,5	-	-	153,0	103,4	161,7	91,2	158,3	73,5
	N	1064	1064	-	-	1087	723	1087	549	1095	370
ST BRISSON	D	18,38	18,38	-	-	18,41	18,44	18,57	19,19	18,32	19,57
(4 blocs)	G	28,24	28,24	-	-	28,95	19,30	29,44	15,88	28,86	11,13
	V	122,6	122,6	-	-	125,8	83,9	126,1	69,6	126,0	49,4
	N	1260	1215	1314	601	-	-	1262	504	-	-
ST AMAND	D	16,67	16,75	16,51	17,95	-	-	16,05	17,68	-	-
(3 blocs)	G	27,50	26,79	28,13	15,21	-	-	25,55	12,38	-	-
	V	172,2	168,0	175,3	97,5	-	-	157,6	79,0	-	-

NB: l'éclaircie du T de ST AMAND ne concerne que quelques chablis préexistants

C a l c u l d e s v o l u m e s

Les volumes ont été obtenus par l'application du tarif ARMEF (Bérard et al. 1982) ; s'agissant d'un tarif de cubage à deux entrées, et l'effet de l'éclaircie sur les diamètres étant évident, en 1989 seuls les volumes de LES HAYERS, ST BRISSON et ST AMAND peuvent être considérés comme valables, car il y a été fait des mesures de hauteur traitement par traitement. Nous fournirons cependant, à titre indicatif, les accroissements en volume pour tous les essais.

RESULTATS

Accroissements en surface terrière

Nous avons choisi de privilégier cette donnée sur l'accroissement en volume, car elle est rigoureusement fiable.

Tableau 4: Accroissements en surface terrière (IG en m2/ha/an)[3]
(Basal area increments (IG in m2/ha/year)

Traitements:		1	2	3	4	5
LODDES	81-84	2,59a	2,48a	2,51a	2,46a	-
	84-86	1,83a	2,14b	2,30b	2,30b	-
	86-89	1,99a	2,31a	2,41a	2,39a	-
	81-89	2,17	2,33	2,42	2,39	-
LE BREUIL	86-89	2,61	-	-	2,40	2,17
BOSSICAN	84-86	2,88a	-	2,52b	2,05c	1,80d
	86-89	2,56a	-	2,68a	2,46a	2,18a
	84-89	2,69a	-	2,61ab	2,30bc	2,02c
LES HAYERS	83-86	1,85a	-	1,51bc	1,65ab	1,41c
	86-89	1,70a	-	1,80ab	2,06b	2,01ab
	83-89	1,78a	-	1,66a	1,85a	1,71a
ST BRISSON	84-89	2,61a	-	2,56a	2,38a	2,02b
ST AMAND	84-87	2,27a	2,01ab	-	1,90b	-
	87-89	1,67a	2,18b	-	2,11b	-
	84-89	2,03a	2,08a	-	1,99a	-

Fig. 5: Douglas élagué sur 6 m à ST AMAND (05/84)
(6 m. height pruned)

[3] Quand sur une même ligne, on trouve, pour 2 traitements, 2 lettres différentes (a,b,c...), l'effet-traitements est significatif au moins au seuil 0,05 : les moyennes sont ensuite comparées entre elles par le test de TUKEY.

Le tableau 4 montre qu'on observe des différences appréciables entre traitements, mais surtout qu'elles peuvent être en sens inverse d'un essai à l'autre ; ainsi le témoin donne la moins bonne production à LODDES, et la meilleure à BOSSICAN (figures 6 et 7) : nous y reviendrons plus loin.

Figure 6: LODDES: IG 81/89

Figure 7: BOSSICAN: IG 84/89

A c c r o i s s e m e n t s   e n   v o l u m e

Nous donnons ci-après dans le tableau 5, à titre indicatif seulement, les accroissements en volumes observés, en m3/ha/an, sur la période comprise entre la 1ère éclaircie et 1989 :

Tableau 5: Accroissements en volume (indicatifs) (IV en m3/ha/an)
(volume increments) (IV in m3/ha/year)

Traitements :		1	2	3	4	5
LODDES	81/89	30,6	27,5	28,6	27,3	-
LE BREUIL	86/89	27,6	-	-	23,4	21,0
BOSSICAN	84/89	26,6	-	21,2	18,5	16,1
LES HAYERS	83/89	24,6	-	20,0	21,2	17,7
ST BRISSON	84/89	26,6	-	22,0	19,5	15,4
ST AMAND	84/89	24,0	20,3	-	19,0	-

A c c r o i s s e m e n t s   e n   d i a m è t r e

Ensemble des arbres (ID)

Le tableau 6, (page suivante) dans sa partie gauche, montre qu'on observe des différences très spectaculaires entre le témoin (traitement 1) et les traitements éclaircis, mais également entre traitements éclaircis, toujours au profit des éclaircies les plus fortes, y compris pour le traitement EL 1/3 + S 1/2 (traitement 5) ce qui semble indiquer qu'on n'a pas

atteint les limites de la non-concurrence.

Tableau 6: Accroissements en diamètre pour l'ensemble des arbres (ID) et les 300 plus gros par hectare (ID300). Unité : 1/10 de mm/an. (Diameter increments for the whole trees (ID) and biggest 300/hectare (ID300). Unit : 1/10 mm/year).

ID/ID300 :		ID					ID300				
Traitements:		1	2	3	4	5	1	2	3	4	5
LODDES	81-84	52	89	78	97	-	90a	116ab	113ab	120b	-
	84-86	34	68	64	81	-	64a	100b	99b	98b	-
	86-89	36	92	97	120	-	65a	111b	113b	131c	-
	81-89	41	85	82	102	-	74a	111b	110b	119b	-
LE BREUIL	86-89	72	-	-	132	150	109	-	-	155	164
BOSSICAN	84-86	94	-	123	130	156	126a	-	144b	143b	162c
	86-89	74	-	112	132	156	104a	-	132b	144bc	163c
	84-89	82	-	116	131	156	113a	-	137b	144b	163c
LES HAYERS	83-86	53	-	66	89	98	88a	-	86a	109b	112b
	86-89	44	-	70	95	118	83a	-	101b	121c	136d
	83-89	48	-	67	92	108	85a	-	93a	115b	124b
ST BRISSON	84-89	73	-	104	121	148	108a	-	129b	141b	156c
ST AMAND	84-87	63	107	-	121	-	101a	126b	-	139b	-
	87-89	41	101	-	116	-	72a	120b	-	134b	-
	84-89	54	105	-	119	-	89a	123b	-	137c	-

Les figures 8 et 9 présentent les résultats des mêmes essais que plus haut (LODDES et BOSSICAN) ; sur ces graphiques apparaissent les accroissements techniques (AT = différence entre D après et D avant éclaircie), ce que le tableau 6 ne prend pas en compte.

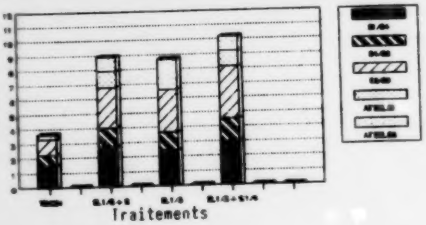

Figure 8: LODDES

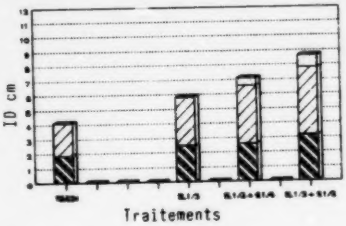

Fig. 9: BOSSICAN

Trois cents plus gros arbres à l'hectare (ID300)

Les résultats sont fournis dans la partie droite du tableau 6. Ils montrent clairement que l'éclaircie profite aussi aux plus gros arbres. A noter que c'est également vrai pour les 200 et même les 100 plus gros. A titre d'exemple, à LODDES, et pour la période 81/89, on a par traitement :

Traitements:		1	2	3	4
ID300 (rappel)	Unité : 1/10 de mm/an	74	111	110	119
ID200		79	118	115	123
ID100		84	128	123	135

Les figures 10 et 11 donnent, pour LODDES 1989, les N/ha par classe de diamètre, en séparant les 100 plus gros, les 100 suivants (200/ha), les 100 suivants encore (300/ha) et le reste :

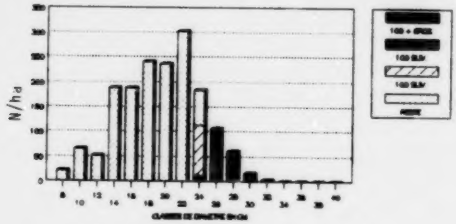

Figure 10: LODDES 1989: témoin
(" " : control)

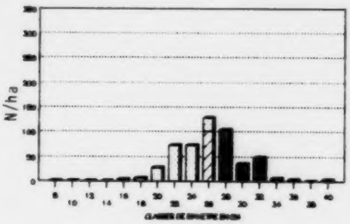

Figure 11: LODDES 1989: EL 1/3 + S 1/4
(" " : treatment 4)

S t a b i l i t é   d e s   p e u p l e m e n t s

Le rapport d'élancement (E = Hg/Dg) est un excellent critère pour apprécier la stabilité d'un peuplement. Nous l'avons calculé par traitement, en 84 et en 89 pour l'essai de ST AMAND, où les mesures de hauteur 89 ont été faites traitement par traitement.

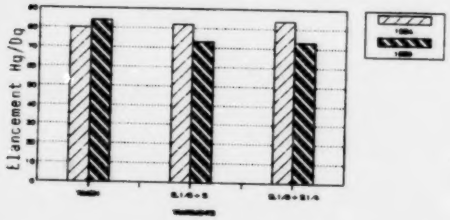

Figure 12: ST AMAND : évolution de l'élancement
(" : Hg/Dg evolution)

La figure 12, ci-contre montre que l'élancement, qui augmente entre 84 et 89 pour le témoin, diminue sensiblement pour le traitement EL 1/3 + S 1/4, et passe en-dessous de 75, ratio considéré comme une limite pour garder une très bonne stabilité (De Champs 1987)

Largeurs de cerne

On ne s'est intéressé qu'aux 300 plus gros arbres à l'hectare (Lc300). Pour calculer les largeurs de cerne, on a admis d'une part que les Douglas avaient mis 3 ans pour atteindre la hauteur 1 m 30, d'autre part que le pourcentage d'écorce, en surface terrière, était constant dans le temps, et égal à 7 %. Les résultats sont présentés sous forme de graphiques (figures 13 à 18) figurant des carottes de sondage ; le premier "cerne", en bas de chaque graphique, correspond au cerne moyen avant la 1ère éclaircie.

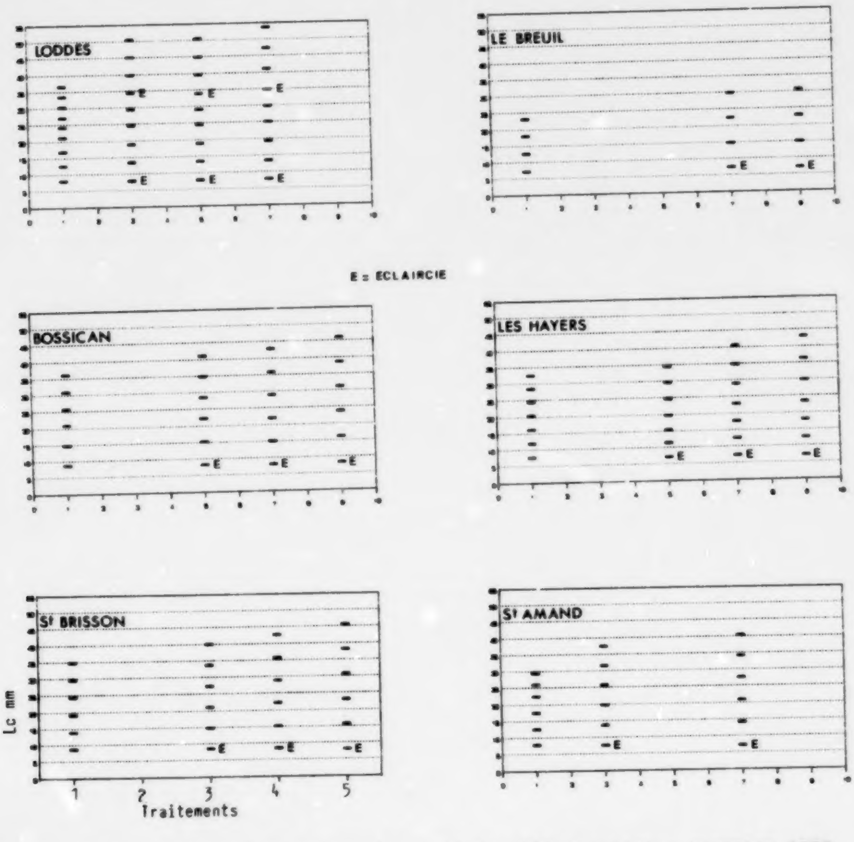

Figure 13 à 18: Largeur de cernes à 1 m 30 des 300 + gros/ha, jusqu'en 1989
(Ring width b.h. of 300 biggest trees/ha, until 1989)

DISCUSSION ET CONCLUSION

On pouvait s'attendre à ce que la sylviculture extrême (traitement 5) pratiquée dans les 4 essais de LE BREUIL, BOSSICAN, LES HAYERS, et ST BRISSON, entraine une sévère perte de production : si c'est effectivement le cas, on peut aussi remarquer que cette perte est très vite atténuée (BOSSICAN), et même annulée (LES HAYERS), malgré les réductions drastiques de matériel végétal sur pied (respectivement 9,57 et 11,50 m2/ha de surface terrière après éclaircie).

Pour une sylviculture un peu plus classique (traitement 4), on constate globalement - sur les 6 essais - une perte minime, au bout de 5 ou 6 ans : 2,22 m2/ha/an pour le traitement 4 contre 2,33 m2/ha pour le témoin. On notera avec intérêt la réaction de LODDES, LES HAYERS et ST AMAND, avec une perte de production sur les 3 premières années, et un GAIN (significatif pour les 3 essais) sur les 2, ou 3, années suivantes. Ce traitement 4 (coupe d'1 ligne sur 3 + 1 arbre sur 4 dans les 2 lignes restantes) apparait comme un excellent compromis : on n'ouvre pas trop le peuplement, évitant ainsi une forte perte de production, mais suffisamment pour éclairer le sol, sans doute le réchauffer, faire évoluer l'humus, et gagner beaucoup en croissance diamétrale.

Tous les types d'éclaircies ont bien entendu un effet considérable sur les accroissements moyens en diamètre. Nous nous sommes attachés plus spécialement aux 300 plus gros arbres à l'hectare (figures 13 à 18) : contrairement à une idée reçue, l'éclaircie profite aussi au dominants ; les différences observées sont significatives par rapport au témoin avec une seule exception (LES HAYERS, traitement 3, sur la période 83-89).

Ces résultats permettent d'affiner nos connaissances sur la sylviculture à appliquer au Douglas, du moins au niveau de la 1ère éclaircie, d'en chiffrer les effets, en particulier sur les arbres destinés à rester jusqu'à la coupe rase, et de mieux connaitre les limites à ne pas dépasser.

Mais la discussion débouche inévitablement sur les problèmes de largeurs de cernes, et de qualité du bois produit : pour beaucoup d'utilisateurs en effet, bois à cernes larges est synonyme de bois médiocre !

Il est exact qu'à une augmentation de la vitesse de croissance correspond une réduction de la masse volumique (Mv kg/m3) du bois produit, elle-même très corrélée aux principales caractéristiques technologiques. Mais il y a de fortes différences d'une essence à l'autre, comme le montre la figure 19 (page suivante) : le Douglas d'au moins 35 ans est avec les pins (sylvestre et maritime) parmi les résineux qui ont les plus fortes masses volumiques. Il semble que si on ne dépasse pas 8 mm de largeur moyenne de cerne, on restera avec une M.v. supérieure à 500 kg/m3, ce qui est tout à fait acceptable pour la plupart des emplois du bois.

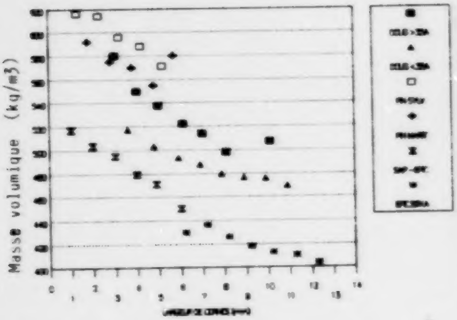

Fig. 19: Effet de la largeur de cerne sur la masse volumique (Effect of ring width on volumic mass for 6 species)

Fig. 20: LODDES 1981, Traitement 4 (Treatment 4) [4]

Ce seuil de l'ordre de 8 mm de largeur moyenne de cerne est compatible avec une sylviculture dynamique, et une 1ère éclaircie EL 1/3 + S 1/4 enlevant 50 % des tiges d'une plantation faite à 1100/1200 plants/hectare : il est même plus vraisemblable qu'on obtienne 7, voire 6 mm de largeur moyenne de cerne, celle-ci ne pouvant que diminuer avec l'âge. On observera d'ailleurs sur les figures 13 à 18 que les cernes produits après la 1ère éclaircie, ne dépassent jamais la largeur moyenne des cernes produits avant ; comme ceux-ci sont passés par un maximum, avant l'entrée en concurrence (De Champs 1988) on voit bien que ce n'est pas le régime d'éclaircie qui déterminera les cernes les plus larges, mais la densité de plantation.

Cependant la largeur des cernes est une chose, la présence de noeuds en est une autre : une éprouvette avec noeuds cassera presque toujours à l'endroit d'un noeud, même si les cernes sont très minces. C'est l'élagage artificiel précoce, de façon à concentrer les noeuds dans un "noyau" de 10 cm de diamètre, qui améliorera la qualité du bois de nos Douglas Français à cernes larges, beaucoup plus qu'une réduction de leur largeur ; et de toutes façons, on voit mal un retour en arrière, complètement anti-économique, pour tenter de produire du "Pin d'Orégon" en France.

Reste un point qui mérite réflexion : pour beaucoup d'usages, et en particulier le déroulage, il faut que l'on ait une bonne homogénéité intra-cerne : ce n'est pas la sylviculture qui peut répondre à la question, mais l'amélioration génétique, par la sélection de Douglas à plus forte densité du bois de printemps, sans réduction de la densité du bois d'été (Nothe 1988).

La conjugaison des efforts des améliorateurs, des reboiseurs, et des sylviculteurs doit permettre, à terme, la production de bois de Douglas à accroissements larges, réguliers, homogènes, et sans noeuds.

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[4] D'après Nepveu et Blachon, 1989: avec l'aimable autorisation de Nepveu et de la Revue Forestière Française.

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PROGRES RECENTS DANS LA SYLVICULTURE DES FEUILLUS EN FRANCE

Louis LANIER

Professeur
Ecole nationale du génie rural, des eaux et des forêts
14, rue Girardet - F-54042 NANCY CEDEX

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RESUME

Après une analyse des grands traits de la politique forestière, telle qu'elle est actuellement en cours de définition à l'échelle européenne, l'exemple de l'organisation de la production forestière, pratiquée de nos jours en France, est évoqué.

L'action du sylviculteur s'appuie d'abord sur la connaissance de la ressource, apportée par les résultats de l'Inventaire forestier permanent. Les estimations de l'accroissement fondent les aménagements sur le principe, renouvelé, du rendement soutenu. La sylviculture pratiquée s'appuie sur l'analyse des stations, qui font l'objet de catalogues, élaborés pour chaque grande région forestière. Des recommandations, résumées dans les orientations régionales de production, servent de guide pour le choix des essences-objectifs ; ces choix privilégient le plus souvent les productions de qualité, moins sensibles aux fluctuations du marché.

L'exemple de la sylviculture du chêne de qualité, spécialité de notre pays montre qu'une longue tradition de soins patients, s'appuyant sur les résultats chiffrés d'expérimentations suivies depuis longtemps, conduit à la mise sur le marché de produits dont le succès ne se dément pas.

Les principaux axes et résultats récents de la recherche forestière sont ensuite évoqués. Parmi les plus significatifs, ceux concernant la mise au point d'une sylviculture fine des grandes essences feuillues classiquement cultivées, hêtre, frêne, merisier, érables, ou même plus exceptionnellement rencontrées telles que l'alisier, permettent d'espérer des avancées significatives dans l'amélioration généralisée de nos forêts.

Mots clés : Politique forestière, inventaire, sylviculture, recherche, feuillus.

PLAN

I. Introduction - Politique forestière - Tendances

II. Connaissance de la ressource - Aménagement - Caractères de la sylviculture des feuillus en France

III. Recherche forestière - Principaux axes - Résultats

IV. Perspectives - Conclusions

I. INTRODUCTION - POLITIQUE FORESTIERE - TENDANCES

De nos jours, on demande toujours plus à la forêt et aux hommes qui la gèrent. Les missions du sylviculteur se multiplient à l'envi : production bien sûr et si possible meilleure et accélérée, mais aussi sauvegarde, protection, aménagement, accueil, maintien d'une vie sauvage, bientôt traitement de l'arbre en ville.

Ces exigences, quelquefois contradictoires dans les pays développés et densément peuplés, de la société vis-à-vis de la forêt imposent au sylviculteur d'adopter des solutions de compromis d'autant plus difficiles à mettre au point que les exigences sont souvent évolutives, changent selon le caprice des modes tandis que la vie de l'écosystème forestier et ses transformations sont nécessairement lentes (Schlaepfer, 1988).

C'est dans ce contexte, encore aggravé par des accidents climatiques qui semblent de plus en plus fréquents au cours de ces dernières années, par les menaces que fait peser ce mystère encore imparfaitement résolu du dépérissement des forêts, que doit s'exercer l'action du sylviculteur européen.

Bien que les produits ligneux ne figurent pas dans le Traité de Rome, fondant la politique économique européenne, au même titre par exemple que les matières premières agricoles, la Communauté européenne se préoccupe de plus en plus de la filière-bois, de son déficit considérable à l'échelle des douze (plus de 90 millions de m3 importés pour une consommation de 190) et de l'évolution probable de ces données dans le sens de l'augmentation des besoins. L'Européen moyen ne consomme en effet annuellement que 0,6 m3 de bois et produits dérivés, contre plus de 2 m3 aux Etats-Unis et encore 1,25 m3 au Japon, pays très fortement importateur.

Comment les déficits prévisibles (plus de 100 millions de m3) seront-ils comblés au début du siècle prochain, alors que les principaux fournisseurs (Pays scandinaves, URSS, Canada et USA pour les résineux, Brésil, Pays tropicaux asiatiques et africains pour les feuillus) se préoccupent **tous** d'une probable et prochaine pénurie, due aux déséquilibres entre l'accroissement de leurs peuplements et les récoltes, en tous cas pour les zones aisément accessibles.

Il est dès lors souhaitable d'établir une véritable politique forestière mondiale, visant à équilibrer besoins et ressources, sans trop compter sur les "mines" que constitueraient les immenses ressources des pays actuellement exportateurs.

Toute politique visant donc à intensifier la production dans les pays gros consommateurs, et en particulier en France où les réserves d'espace, les massifs forestiers insuffisamment productifs, les terres libérées par l'agriculture offrent de nouvelles opportunités, mérite donc d'être encouragée (Gadant, 1989).

C'est dans le cadre de cette politique dynamique de la forêt, en Europe et en France que se placent les progrès en cours en matière de sylviculture.

Cette politique forestière, résolument moderne, s'appuie, pour ce qui concerne la France, sur la variété des sols et des climats, sur l'excellence de ses productions agricoles conduisant à libérer de nouvelles terres, et sur une longue tradition forestière, complétée par une expérience de quarante années de reboisement dont on commence à récolter les fruits.

Une bonne connaissance de la ressource, une organisation rationnelle et hiérarchisée, allant depuis les orientations régionales de production jusqu'à l'aménagement détaillé de chaque massif, une desserte complète, une bonne technicité et une couverture suffisante du terrain par des professionnels de plus en plus compétents, tout concourt à assurer ces indispensables progrès.

Après une analyse succinte de cette ressource et des directives en matière d'aménagement, nous nous efforcerons dans un deuxième chapitre, de caractériser rapidement la sylviculture actuellement pratiquée, puis dans un troisième chapitre plus important d'indiquer l'organisation, les principaux axes et résultats de la recherche forestière, en sylviculture des feuillus essentiellement.

Nous tirerons enfin quelques conclusions en forme de perspectives.

II. CONNAISSANCE DE LA RESSOURCE - AMENAGEMENT - CARACTERES DE LA SYLVICULTURE DES FEUILLUS EN FRANCE

Depuis un peu plus de trente ans (Ordonnance du 24.09.1958), notre pays dispose d'un Service d'inventaire forestier, chargé d'un inventaire permanent de l'ensemble des ressources forestières, inventaire indépendant des questions de propriété.

Les résultats de cette couverture complète du territoire, qui parcourt chaque année une dizaine de départements, sont particulièrement instructifs. En tenant compte de l'obligatoire imprécision de ces résultats, qui tient au mode d'échantillonnage (incertitude de l'ordre de 2 % sur les surfaces et de 3 % sur les volumes sur pied et accroissements), on peut

juger clairement des conséquences d'une politique forestière cohérente conduite depuis près de deux siècles mais avec plus d'intensité depuis une quarantaine d'années et visant à maintenir une production soutenue, diversifiée et de qualité, tout en augmentant par des reboisements, plus ou moins importants selon les régions, les surfaces forestières et la production.

Les tableaux sélectionnés ci-contre, extraits de données récentes publiées dans la Revue forestière française (Deheeger, 1989), résument la situation et son évolution.

Principaux résultats de l'Inventaire forestier national

Propriétaires / Rubriques	Forêt domaniale	Forêt des collectivités	Forêt privée	Total
Surface (ha) ...	1 423 720	2 222 750	193 857	13 840 327
Volumes* sur pied (m3)	255 716 500	346 836 500	1 095 556 800	1 698 119 800 dont **1 047 382 000 feuillus** 650 737 800 résineux
Accroissements (m3/an)	6 534 050	8 908 950	44 849 100	60 292 100

*Chiffres ne concernant que les forêts de **production** (environ 10 millions d'hectares au total)

Si l'on tient compte d'une récolte annuelle de l'ordre de 30 à 35 millions de m3 et d'une consommation non comptabilisée (bois de feu et divers) estimée à 10 millions de m3, on voit que la forêt française est en phase de capitalisation rapide.

Ceci transparaît clairement du tableau suivant établi pour 59 départements (les plus forestiers) où deux passages successifs de l'Inventaire permettent d'utiles comparaisons.

Accroissement en m3

	Forêt domaniale	Forêt communale	Forêt privée	Total
1er passage	3 992 150	5 463 450	25 478 600	34 934 200
2ème passage	4 408 250	6 751 600	37 021 650	48 181 500
Variation	+ 416 100	+ 1 288 150	+ 11 543 050	**+ 13 247 300**
en %	+ 10,4	+ 28,8	+ 45,3	

C'est donc surtout la forêt privée qui "monte en puissance" du fait même des reboisements de plus en plus nombreux et productifs de l'après-guerre.

Or une évolution très nette se produit au cours des vingt dernières années (tableau III en annexe) : d'une part une diminution des surfaces reboisées annuellement (de 50 000 ha environ vers les années 1970, à 20-25 000 ha dans les années récentes), d'autre part essentiellement depuis 1974 et les extensions des aides du Fonds forestier national à la plantation des grands feuillus sociaux (chênes, hêtre, érables, frêne, merisier...). Une notable proportion de reboisements en feuillus, plus du quart des surfaces certaines années.

Les orientations régionales de production indiquent maintenant les essences à recommander en fonction des conditions stationnelles et les feuillus apparaissent de plus en plus souvent dans les choix les plus vivement recommandés. Ceci nous conduit à évoquer les directives d'aménagement qui fixent les objectifs à long terme.

Le récent Manuel d'aménagement* édité par l'Office national des forêts rappelle entre autres les règles applicables pour la gestion des forêts de l'Etat et des collectivités publiques. Les plans de gestion pour les forêts privées d'une certaine importance peuvent s'en inspirer.

On y souligne l'importance d'une bonne reconnaissance des types de station et de leurs potentialités. Les catalogues de station existent ou sont en cours d'établissement pour une proportion importante des grandes régions forestières de France : le quart nord-est, l'ouest, une partie du centre et du sud-ouest de notre pays sont déjà couverts. Mais plusieurs années seront encore nécessaires pour que l'ensemble des régions forestières soit doté d'un catalogue. Il faudra encore qu'à l'occasion de la mise au point des orientations de production ou des révisions d'aménagement des massifs eux-mêmes, une exacte correspondance soit établie entre la cartographie des stations et les vocations forestières.

Partout où ce sera possible l'**objectif de qualité** sera recherché.

Un dialogue intéressant et d'une grande importance par la pierre qu'il apporte à l'élaboration d'une politique forestière, qui définit des choix pour le long terme, vient de s'établir entre un responsable administratif (Barthod, 1988) et un ancien chercheur spécialiste des problèmes de qualité des bois (Polge, 1989).

L'enjeu est d'importance car les choix en matière sylvicole se font une fois, pour le très long terme souvent, et ne sont plus guère modifiables ultérieurement, les bois les plus recherchés ayant **toujours** une caractéristique commune, qui est la **régularité** des accroissements.

*DUBOURDIEU J., 1989 - Manuel d'aménagement.
Office national des forêts, Département recherches techniques, Fontainebleau, 150 pages.

On se reportera aux conclusions de Schütz (1981) ou à nos propositions récentes (Lanier, 1985) pour se rendre compte que notre sylviculture se doit de fournir, partout où la chose est possible, des produits de la plus haute qualité possible, c'est-à-dire homogènes, de droit fil, sans noeuds et beaux. C'est le "haut de gamme" qui maintient le mieux ses cours.

Voyons maintenant quelles sont les principales caractéristiques actuelles de la sylviculture des feuillus en France.

A l'exemple du chêne, qui en est le plus abondant et le plus spectaculaire fleuron, la sylviculture produit des bois de qualité en se fondant sur une longue tradition, sur la régénération naturelle des "crus" de chênes réputés, sur des soins patients (et coûteux) dès le jeune âge et sur des coupes d'amélioration, longtemps prudentes, permettant d'obtenir une longueur suffisante de fûts sans noeuds et aux cernes fins et réguliers.

C'est un choix, fixé par les aménagements avec des révolutions nécessairement longues (180 à 240 ans) pour obtenir les dimensions de produits les plus rémunératrices (tranchage, menuiserie fine, merrains). Mais c'est un choix sage, dans la mesure où la demande de ces produits de qualité est forte et se reflète dans les cours du marché.

Cette sylviculture du chêne de qualité est maintenant bien au point. Elle bénéficie, pour en faciliter la mise en oeuvre, de tables de production (Pardé, 1962) et de normes de sylviculture (Pardé, 1978) s'appuyant sur les résultats des nombreux dispositifs expérimentaux, mis en place, pour les plus anciens, depuis une centaine d'années et régulièrement suivis depuis (Oswald, 1981).

Pour la majorité des autres feuillus (hêtre, frêne, merisier, érables, noyers), les qualités du bois recherchées étant beaucoup moins liées à la finesse des cernes, voire même indépendantes de celle-ci, la sylviculture est plus dynamique et s'efforce d'obtenir, le plus rapidement possible, les dimensions les plus rémunératrices.

Ainsi des tables de production existent maintenant pour le chêne et pour le hêtre (Vannière, 1984) et sont en cours d'établissement pour le frêne, le merisier, les grands érables et le chêne rouge.

Voyons maintenant les apports de la recherche dans les divers domaines liés à la sylviculture.

III. LA RECHERCHE FORESTIERE - PRINCIPAUX AXES - RESULTATS

Longtemps réduite à un minuscule diverticule de l'enseignement forestier, la recherche forestière a connu, depuis trente ans un développement remarquable. Elle est aujourd'hui par le nombre et la qualité de ses chercheurs, au niveau des autres pays forestiers européens.

A l'image de la forêt française, sa recherche est très diversifiée : elle est à la fois publique (Institut national de la recherche agronomique - INRA ; Centre national du machinisme agricole du génie rural, des eaux et des forêts - CEMAGREF ; Centre technique forestier tropical - CTFT ; Etablissements d'enseignement) ou plus ou moins privée (Association forêt cellulose - AFOCEL). Diversifiée géographiquement, avec des établissements importants dans le nord-est, la région centre et parisienne, le sud-est méditerranéen et le sud-ouest atlantique, sans compter les territoires d'outre-mer, la recherche couvre également l'essentiel de l'éventail thématique par grandes essences (hêtre, chênes, pins, épicéas, douglas...) ou par disciplines (botanique, génétique, pédologie, sylviculture, protection de la forêt...). Bien mieux, elle est articulée - depuis plus ou moins longtemps et avec des programmes plus ou moins coordonnés - avec des organismes de recherche appliquée au terrain ou de développement à leur tour très nombreux (trop ?) et diversifiés.

Ainsi le CEMAGREF et l'AFOCEL-Association sur la rationalisation des matériels d'exploitation forestière - ARMEF, bien sûr, mais aussi l'Institut pour le développement forestier - IDF, les centres régionaux de la propriété forestière, les chambres d'agriculture, les coopératives, le Centre technique du bois et de l'ameublement - CTBA... concourrent à la mise en forme et à la diffusion des résultats scientifiques. Tout récemment (1987), l'Office national des forêts vient de se doter d'une organisation en cellules scientifiques et techniques, à la fois chargées de la collecte des besoins en recherche exprimés par les services de terrain et de la fourniture des renseignements existants susceptibles d'être érigés en règles de gestion. Tout est-il parfait et les besoins réels sont-ils couverts ? Certainement pas, le domaine d'études étant très complexe, les résultats étant le plus souvent longs et difficiles à obtenir.

Quelle est la place dans cet ensemble de la recherche en sylviculture et quels sont les résultats récents les plus significatifs ?

Recherches en sylviculture

Si l'on considère que la sylviculture est l'art d'appliquer les connaissances scientifiques acquises sur le fonctionnement des écosystèmes forestiers en vue de leur perpétuation et de la satisfaction des besoins des hommes, toutes les recherches conduisant à l'acquisition des connaissances en matière de forêt verront un jour ou l'autre une application en sylviculture.

Nous nous bornerons néanmoins, afin de mieux cerner notre sujet aux travaux portant, soit sur la phase initiale de la vie des peuplements forestiers (régénération, soins aux jeunes peuplements), soit sur la conduite des peuplements eux-mêmes (coupes d'amélioration, soins aux arbres, liaisons entre traitements sylvicoles et qualités des produits...). L'éventail en est déjà considérable et les résultats acquis utilisés, par exemple dans le cas des chênes et du hêtre.

Régénération

La phase fondamentale est d'ordre génétique : il s'agit d'assurer le maintien des ressources de gênes et de conserver, de "classer" les meilleurs peuplements, en assurant le renouvellement prioritaire des individus dont les qualités sont exceptionnelles. C'est d'ailleurs l'un des objectifs de l'amélioration des peuplements par la coupe sélective. Elle doit normalement conduire, par sélection massale et sanitaire, à ne plus conserver, au moment des coupes de régénération que les individus, au moins phénotypiquement supérieurs.

C'est pourquoi, le Centre d'études sur le machinisme agricole, le génie rural et les eaux et forêts a retenu pour le chêne pédonculé par exemple 3 404 hectares en 126 peuplements classés et pour le chêne rouvre 12 255 hectares en 117 peuplements classés sur lesquels, seuls, les graines doivent être récoltées, en vue de leur diffusion.

Des efforts importants ont été nécessaires pour mettre au point des procédés de conservation, centralisés et efficaces, des méthodes de levée de dormance des graines (Lacroix, 1986 ; Muller et al., 1985), puis des procédés modernes d'éducation des plants (Garbaye, 1986).

Dans le cas des chênes, la distinction dès le stade de la graine entre chêne rouvre et chêne pédonculé (Dupouey et al., 1989) est d'autant plus intéressante, en particulier lorsque des plantations sont nécessaires (compléments à des régénérations naturelles insuffisantes ou reboisements de terres nouvelles) que les dépérissements constatés après les sécheresses de 1976 et de 1983, à Tronçais et dans le Pays basque, se sont presqu'exclusivement manifestés sur des chênes pédonculés d'origine artificielle. Ces manifestations (Becker et Levy, 1982, 1983 ; Guillaumin et al., 1985) pourraient parfaitement se renouveler après l'été 1989, qui dans certaines régions du sud-ouest en particulier a été encore plus déficitaire en eau que l'été, pourtant exceptionnel, de 1976.

Pour ce qui **est des soins aux jeunes peuplements**, toute une série de dispositifs expérimentaux ont été installés, en particulier par l'Office national des forêts (voir liste en annexe), en vue d'optimiser, à la fois sur le plan technique et économique - ces travaux, indispensables, étant toujours très coûteux - l'emploi des moyens envisageables (chimiques, mécaniques ou humains) (cf. Lanier, 1981).

A propos de l'emploi des phytocides en sylviculture, le CEMAGREF, en collaboration avec l'INRA, vient d'éditer un document qui synthétise les connaissances actuelles sur les traitements par produits chimiques en forêt. Bien qu'encore relativement peu employés en France, sauf pour les dégagements sélectifs et pour les débroussaillements pare-feux en région méditerranéenne, les phytocides devraient, avec les progrès de la recherche les concernant, trouver de nouveaux emplois dans les années à venir (Gama et al., 1987).

Nous n'insisterons pas sur les découvertes récentes en matière de conduite des peuplements, un consensus semblant maintenant s'établir sur le repérage de tiges d'avenir vers le tiers de la vie des peuplements (70 ans chez le chêne rouvre, 40 ans chez le hêtre), suivi d'éclaircies plutôt par le haut, peut-être un peu plus énergiques que par le passé dans le cas du chêne, et certainement plus vigoureuses pour tous les autres feuillus.

Détaillons quelque peu le cas du hêtre qui a, surtout depuis la parution de la monographie de 1981*, bénéficié dans notre pays à la fois d'un regain d'intérêt et, au cours des récentes années, de prix de vente bien plus favorables.

Sylviculture du hêtre

Les avancées les plus récentes en matière de sylviculture du hêtre proviennent des résultats préliminaires obtenus par les spécialistes en qualité des bois qui ont confirmé :

- que le bois de hêtre à faible rétractibilité, recherché pour les emplois rémunérateurs (déroulage, ébénisterie fine), étaient obtenus lorsque les houppiers étaient bien développés (Polge, 1973, 1981) ;

- que, dans ce cas, lorsque les arbres bénéficiaient d'éclaircies vigoureuses et par ailleurs étaient bien droits, verticaux avec des houppiers larges et symétriques, les contraintes de croissance étaient considérablement réduites (Ferrand, 1982 ; Polge op. cit., 1981).

Dès lors, la désignation aussi précoce que possible d'arbres d'avenir et les éclaircies vigoureuses à leur profit constituent des règles de conduite des peuplements d'autant plus favorables qu'elles conduisent à des révolutions plus courtes, donc à une meilleure rentabilité économique.

Il restait à préciser l'âge le plus précoce possible à partir duquel pouvaient être valablement désignées les tiges d'avenir et l'âge le plus tardif jusqu'auquel pouvaient être entreprises des éclaircies de rattrapage, dans des peuplements laissés jusque là trop denses ou conduits trop prudemment (ce qui est le cas général en France dans des hêtraies où la régénération naturelle est réussie).

Des réponses ont été apportées récemment sur ces points fondamentaux (Bouchon, Dhôte et Lanier, 1989) : en conditions normales et si les dégagements-nettoiements ont été correctement effectués, la désignation des 100 à 120 tiges de qualité qui iront au terme de la révolution (120 ans) ne peut guère intervenir avant 40 ans, des inversions de rang social et des descentes de cimes pouvant se produire lorsqu'on dégage énergiquement des arbres de moins de 40 ans. La tige de 8 à 12 mètres, nette de noeud,

*TEISSIER du CROS E., 1981 - Le hêtre.
INRA (ouvrage collectif), 613 p.

	Age	
Génération précédente	0	Régénération acquise (ou complétée par plantations)
Coupes de mise en lumière		Phase des dégagements de semis (installation du cloisonnement cultural)
↓	10	Phases des dépressages. Nettoiements
Coupe définitive	20	Derniers nettoiements
		Première éclaircie
	30	Repérage des candidats
	40	Désignation des tiges d'avenir
		↓
	60	Eclaircies (rotation 6 à 8 ans)
		↓
	80	
	90	Coupes d'hygiène
	100	↓
	110	Préparation de la régénération
		Préparation du sol
		Mise en régénération

n'est d'ailleurs pas encore totalement formée à cet âge. Par ailleurs, le hêtre - et ce résultat était assez inattendu - réagit bien aux éclaircies, même fortes, jusqu'à un âge avancé, au moins jusqu'à 70 ans. La stimulation de l'accroissement individuel, en surface terrière et en volume est considérable. Mais il reste à déterminer l'influence, sans doute néfaste sur les qualités d'homogénéité du bois, qui résulte d'éclaircies fortes trop tardives.

Il est de loin préférable de conduire, dans le cas du hêtre, une sylviculture dynamique, après des nettoiements soigneux, qui respecteront utilement* une proportion notable de feuillus (grands érables, chênes, fruitiers) ou de résineux (mélèze) associables au hêtre, qui peut être schématisée par le graphique suivant

Rien n'empêche de désigner 120 à 140 tiges d'avenir, lorsque la qualité du peuplement le permet, pour tenir compte des risques de chablis et pour récolter quelques belles tiges lors des dernières éclaircies précédant la mise en régénération.

Sylviculture d'autres feuillus

FRENE : espèce recherchée dont la sylviculture peut paraître au point: l'analyse des stations favorables (Thill, 1970 ; Faure et al, 1975), la mise au point d'indices de productivité (Le Goff, 1982), les corrélations entre stations et productivité (Le Goff et Levy, 1984) permettent de recommander un choix optimisé des sites favorables à la culture de l'essence et une sylviculture dynamique, visant à obtenir vers 60-70 ans des grumes de 50 à 60 cm de diamètre, sans coeur noir (Lanier, 1986).

MERISIER : depuis quelques années surtout, sous l'impulsion des organismes de développement en forêt privée (Hubert, 1980), le merisier connaît un engouement remarquable, sans doute fondé sur des prix de vente élevés dans un marché du meuble demandeur.

Les plantations nouvelles ont bénéficié des résultats de recherches ayant permis de sélectionner les individus les plus remarquables, de les multiplier végétativement avant de les mettre en place sur les stations les plus favorables.

Dans le mouvement général en faveur des feuillus et même si une sylviculture spécifique n'est pas mise au point dans chaque cas, de nombreuses essences feuillues bénéficient d'un regain d'intérêt ou d'une attention nouvelle.

*La hêtraie, du fait du tempérament étouffant de l'espèce principale, a tendance - aidée le plus souvent par le sylviculteur - à se retrouver rapidement très pure, trop pure. Or, il est bien connu que cette monoculture, même d'une essence climacique est dommageable à l'évolution des humus (tendance au moder voire au mor) et conduit aux risques phytosanitaires accrus (**Cryptococcus** entre autres).

C'est ainsi que le châtaignier, malgré les risques phytosanitaires dus à l'encre (**Phytophthora** spp.) ou au chancre (**Endothia parasitica**) retrouve, dans les balivages des taillis, une certaine place. Malheureusement, le grave défaut de la "roulure" n'a pas encore trouvé de remède sylvicole.

Les grands érables sont de plus en plus plantés en enrichissement, ainsi que des essences nouvelles toutes feuillues, de plus en plus diversifiées (chêne rouge bien sûr, mais aussi tulipier et fruitiers forestiers).

C'est d'ailleurs sur un projet de recherches concernant l'un de ces fruitiers forestiers que nous allons fournir quelques perspectives, annonçant nos conclusions.

IV. PERSPECTIVES ET CONCLUSIONS

Récemment, nous avons fait choix, pour développer un projet de recherches pluridisciplinaires sur une essence feuillue méconnue de l'alisier torminal.

Pourquoi cette essence et comment l'étudier ? Il s'agit d'une rosacée sauvage arborescente, un **Sorbus**, dont notre pays est le premier producteur mondial.

Mais nous ne connaissons de façon précise, ni le volume sur pied, ni l'accroissement, ni même la répartition exacte. Nous savons seulement qu'il s'agit d'une essence disséminée, dont l'aire de répartition est une des plus vastes d'Europe, des rives de la Baltique jusqu'à la Méditerranée (et même au delà, en Algérie et au Maroc) et de l'Espagne à l'Iran.

Cette vaste amplitude écologique, l'adaptation remarquable à des types climatiques très variés, une probable existence d'écotypes divers en rendent déjà l'étude intéressante.

Mais quelques caractéristiques propres, à savoir une adaptation possible aux sols à tendances hydromorphes, une remarquable aptitude à subsister, bien que dominée par les grands feuillus sociaux, chêne et hêtre, enfin une qualité technologique et esthétique remarquable de son bois renforcent l'intérêt de l'étude. Les prix de vente des plus beaux spécimens en font l'une de nos essences les plus précieuses.

Le projet de recherche comprend donc :

- l'étude phytosociologique et écologique approfondie permettant d'expliquer la répartition actuelle et d'envisager des extensions possibles,

- l'étude des qualités du bois, en liaison avec les stations,

- parallèlement, recherche de toutes les informations souhaitables sur la biologie, la morphogénèse, la génétique, les associés mycorhiziens, l'aptitude à la multiplication végétative... permettant à terme une promotion de l'essence.

Un article récent (Lanier et al., 1990) fait le point sur l'état actuel de la question. Des publications ultérieures rendront compte, au fur et à mesure, de l'état d'avancement des travaux.

Ces préoccupations nouvelles ne doivent pas conduire à négliger la connaissance et la diffusion des résultats de recherche les plus prometteurs, concernant les grandes essences feuillues.

Nous en retiendrons quelques uns, en sélectionnant ceux qui sont porteurs des ouvertures les plus significatives. Ainsi, le chêne à Tronçais.

Les études de Polge (1973) et de Polge et Keller (1973) retrouvaient, en utilisant des méthodes modernes d'analyse densitométrique, les raisons connues des corrélations entre finesse des cernes, faible densité du bois, faible rétractibilité et aptitude au tranchage. Mais chemin faisant, ils découvraient dans cette même forêt de Tronçais, des chênes, qualifiés de paradoxaux qui, bien que présentant des accroissements assez larges - ce qui aurait dû leur conférer une certaine dureté, une forte densité, donc de moins bonnes qualités pour le tranchage - bénéficiaient d'une faible densité.

Des recherches ultérieures ont montré que ces chênes existaient - malheureusement en proportions assez faibles dans la majorité des peuplements de chênes échantillonnés.

L'intérêt de ces arbres est évidemment considérable puisque, si l'on arrivait à les sélectionner, on arriverait par une sylviculture dynamique, de type adopté pour le frêne ou le chêne rouge, à obtenir des billes de tranchage à 100 ou 120 ans au lieu de 180 à 240.

Comme vers la même époque, avait été mise au point une méthode de multiplication végétative du chêne, à partir de rejets de souches (Garbaye et al., 1977). On pouvait espérer - ce qui a été fait depuis - sélectionner les chênes présentant ces caractères favorables, les multiplier végétativement et les mettre en place en forêt.

De nouveaux progrès ont été accomplis depuis, des chênes ayant été obtenus à partir de cultures de tissus (vitroplants) (Favre et Juncker, 1986), puis artificiellement mycorhizés. Lei et Dexheimer (1986) ont en effet montré que ces vitroplants, non seulement étaient aptes à être mycorhizés artificiellement selon des méthodes maintenant classiquement employées (Le Tacon et al, 1983), mais qu'en plus les mycorhizes obtenues, uniquement avec les associés fongiques communément inféodés aux chênes, étaient morphologiquement et physiologiquement très proches de celles observées en milieu naturel.

Il y a donc de bons espoirs d'aboutir par cette filière très artificielle à des plants qui auraient un bon comportement, une fois transférés en milieu forestier.

Dans le même ordre d'idées, la multiplication végétative à partir d'explants (tigelles ou boutures de noeuds) a été obtenue par Noëlle Dorion et al. (1987) pour des ormes supposés résistants à la Maladie hollandaise (**Ceratocystis ulmi**). L'acclimatation et la croissance n'ayant pas posé de problèmes particuliers, il y a là une voie prometteuse pour reconstituer un jour les plantations d'ormes décimés par la maladie.

C'est sur cette note d'espoir de voir un jour, grâce aux progrès coordonnés accomplis par les chercheurs, reconstitués les peuplements d'espèces menacées et constitués des peuplements plus vigoureux, plus productifs, que je souhaiterais conclure.

La sylviculture des feuillus est un bon choix pour l'avenir.

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Tableau III - Ventilation des surfaces mises en boisement selon les essences utilisées

Essences	Surface annuelle mise en boisement (en ha)																
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
RESINEUX	**39 899**	**43 048**	**46 376**	**45 876**	**45 701**	**43 038**	**37 904**	**33 141**	**29 406**	**31 107**	**27 416**	**29 031**	**29 031**	**23 774**	**19 822**	**16 915**	**15 871**
(en %)	**90,9 %**	**91,2 %**	**90,5 %**	**90,1 %**	**91,2 %**	**90,4 %**	**87,6 %**	**83,7 %**	**83,3 %**	**80,9 %**	**78,3 %**	**76,8 %**	**71,8 %**	**72,9 %**	**76,9 %**	**78,17%**	**76,85%**
dont :																	
- Pin maritime	6 206	6 013	6 334	7 176	7 375	8 251	7 526	6 215	8 905	8 263	6 864	6 724	6 156	5 049	4 604	3 291	3 221
- Pin noir d'Autriche	1 342	1 097	1 574	1 785	1 790	829	679	956	598	787	745	1 123	1 184	1 380	520	518	428
- Pin laricio	3 280	3 439	3 700	3 993	3 909	3 819	3 606	3 339	2 900	2 574	3 088	3 336	3 417	3 174	2 643	1 831	2 325
- Pin sylvestre	652	636	854	783	796	512	580	459	443	468	554	501	530	383	381	270	242
- Autres pins	427	417	527	532	400	436	349	226	447	366	650	269	453	373	498	154	162
- Sapin pectiné	3 479	3 421	2 765	3 301	3 435	3 383	2 109	2 312	1 170	1 846	1 384	1 543	1 637	1 166	895	1 027	880
- Sapin de Vancouver	1 089	745	614	525	404	386	372	302	197	248	206	167	167	161	141	125	163
- Sapin de Nordmann .	647	1 277	1 298	1 067	715	927	717	865	255	314	291	408	378	455	415	183	132
- Epicéa commun	9 428	10 823	9 987	9 429	9 604	9 182	7 256	6 778	4 354	5 086	3 761	3 804	3 986	3 117	2 328	2 769	1 889
- Epicéa de Sitka ...	2 324	2 142	2 888	2 334	1 710	1 984	1 627	1 337	901	944	582	496	547	636	466	334	329
- Douglas	10 751	12 531	15 032	13 779	14 515	12 304	12 527	9 634	8 307	9 264	8 518	9 378	9 418	6 829	5 795	5 429	4 917
- Autres résineux ...	294	507	703	1 172	1 048	1 035	557	910	929	967	765	1 282	1 150	1 071	1 136	984	1 183
FEUILLUS	**4 016**	**4 155**	**4 853**	**5 033**	**4 404**	**4 562**	**5 922**	**6 209**	**5 908**	**7 333**	**7 579**	**8 771**	**11 351**	**8 851**	**5 938**	**4 722**	**4 809**
(en %)	**9,1 %**	**8,8 %**	**9,5 %**	**9,9 %**	**8,8 %**	**9,6 %**	**12,4 %**	**16,3 %**	**16,7 %**	**19,1 %**	**21,7 %**	**23,2 %**	**28,2 %**	**27,1 %**	**23,1 %**	**21,83%**	**23,15%**
dont :																	
- Noyer, Eucalyptus	281	278	273	274	277	353	1 036	386	182	200	222	289	304	170	221	177	888
- Peuplier	3 723	3 866	4 574	4 759	4 126	4 077	4 237	3 943	3 717	7 133	7 357	8 482	11 047	8 681	5 717	4 545	3 921
dont I.214	2 466	2 321	2 635	2 531	1 942	1 503	1 536	1 516	1 106	1 187	699	650	465	424	403	277	212
Robusta	899	1 131	1 582	1 706	1 669	1 937	1 853	1 601	1 720	2 067	2 053	1 914	2 023	1 496	1 027	877	230
autres pp. euram	325	378	331	476	453	545	695	746	891	1 157	1 398	1 534	1 704	1 639	1 175	922	634
pp. deltoïdes	33	36	26	44	61	92	153	80									
- Autres feuillus ...	12	11	6	-	1	132	849	1 870	2 009	2 722	3 207	4 384	6 855	5 122	3 112	2 469	2 845
TOTAL	**43 915**	**47 203**	**51 229**	**50 909**	**50 105**	**47 600**	**43 826**	**39 350**	**35 314**	**38 440**	**34 995**	**37 802**	**40 382**	**32 625**	**25 760**	**21 637**	**20 680**

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ECOLOGY AND REGENERATION OF KOREAN OAK SPECIES

D. K. Lee and M. H. Suh

Department of Forestry
Seoul National University
Suwon 441-744, Republic of Korea

FDC: 181.21: 23: 176.1 *Quercus* spp.

SUMMARY

The species composition of oaks and their associations at natural forests, and the effects of light intensities on their seedling growth were examined to understand their ecological characteristics. Also, reproduction and regeneration from seeds or sprouts were investigated at the field situations. All the study areas were dominated by *Quercus* species. However, species composition becomes diverse with decreasing latitude. High latitudinal areas in Kyunggido are characterized as oak forests, low latitudinal areas in Chullanamdo as mixed hardwood forests with oaks, and mid-latitudinal areas in Chungchongnamdo as pine-oak forests. *Quercus mongolica* showed highly positive associations with *Q. variabilis*, but did rather negative ones with *Q. serrata*. *Q. serrata* was the best in growth rate of height and dry weight under most of the light intensities. Much dry weights were distributed to roots at all the intensities for all the species. Covering or mulching over the seeded acorns helped better regeneration of oaks. Sprouting is useful for reproducing *Q. mongolica* and *Q. dentata*.

Keywords: *Quercus*, species composition, species association, light intensity, regeneration

INTRODUCTION

The oaks, native to Korea, grow in China and also in Japan. Most of the forest stands in Korea are not characterized as primary virgin forests but rather as secondary forests, which are pine forests, pine-oak forest and mixed forests with oaks. Like this, oaks occupy most of the Korean forests. Oaks are useful species in Korea: wood for timber, mushroom or charcoal production, and acorns for food and

feed. Their stock volumes are estimated to be about 27% of the total even though they had not been well managed. However, neither their ecological characteristics were well known or the proper regeneration techniques were defined.

Knowledge about the ecological niche of a species is essential to the establishment of proper propagation and regeneration methods. Hutchinson(1957) presents the niche, a multi-dimensional hypervolume, defined by the sum of all the interactions between an organism and its abiotic, and biotic environments. However, it is convenient to subdivide this multi-dimensional space into two separate directions such as nutrient niche and habitat niche(Putman and Wratten, 1984).

Of habitat niche, the effect of light on oak growth was only tested in this study because of its great influence. Species composition was also studied at the stands composed mainly with oaks.

The objectives of this study were 1) to examine the species composition of six deciduous oaks and the associations between them at natural forest stands, 2) to compare the growth of those oak seedlings under different light intensities, and 3) to investigate the proper reproduction and regeneration methods at the field conditions.

MATERIALS AND METHODS

The forest stands which consist mainly of oaks were selected for study(Figure 1). The altitude of those areas existed between 300 and 800m from the sea level. The annual total precipitation in those areas ranged from 1,200 to 1,700mm. Most of the soils were sandy loam in texture and formed in deeper granite material.

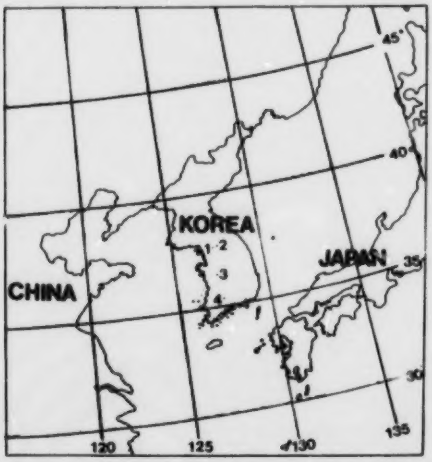

Figure 1. Location map of the study area.

Kwangju in Kyunggido(No.1 in Figure 1) is located at 37° 18'N and 127° 18'E, Yangpyung in Kyunggido(No.2) at 37° 28'N and 127° 40'E, Mt.Kyeryong area in Chungchongnamdo(No.3) at 36° 20'N and 127° 14'E, and Mt. Baekun area(No. 4) in Chullanamdo at 35° 05'N and 127° 40'E, respectively.

The point-quarter sampling method was adopted for the analysis of species composition in study areas. Sample trees(>6cm in DBH) standing at the nearest distance from a sample point were chosen from four different directions, and their diameters at breast height(DBH) were measured. Relative density(RD), relative frequency(RF), relative coverage(RC) and importance value(IV) were calculated on the basis of DBH for each species. Shannon-Weaver's species diversity index(H') was calculated in the study areas to understand the diversity of species composition. The evenness(J') and dominance(1-J')for each species were also calculated. The associations among six oak species growing in Kwangju and Mt.Baekun areas were examined using Chi-square matrices.

The potted seedlings of six deciduous oak species such as Quercus acutissima, Q. aliena, Q. dentata, Q. mongolica, Q. serrata and Q. variabilis were grown for four months under five different light conditions: 5%, 25%, 50% and 75% of full daylight, and full daylight. Height growth and dry weights were measured.

Seed germination of Q. acutissima and Q. mongolica was tested at the clearcut sites where Q. acutissima and Q. mongolica had grown, and also within Q. acutissima and Q. mongolica stands. Three experimental plots (20m x 20m) were prepared for each of those stands and then five small plots(90cm x 90cm) were established in each of the experimental plots. The twenty acorns from each of Q. acutissima and Q. mongolica were seeded in each of the small plots, and then five treatments were applied to seeded acorns: wire-net cover, nylon-net cover, mulching with litters, scratching, and control.

Stump sprouting was also examined at Q. mongolica and Q. dentata stands located in Jeongseon-gun, Kangwondo after clearcutting. One-year growth in diameter, height, dry weight, and number of sprouts were measured.

RESULTS AND DISCUSSION

Species Composition of Oaks among Study Areas

A total of 22 tree species appeared in Kwangju area, 32 species in Yangpyung area, 49 species in Mt. Kyeryong area and 36 species in Mt.Baekun area(Table 1). There were only 8 species which appeared commonly in all of the study areas.

Table 1. Various diversity indices in four study areas

	Kwangju	Yangpyung	Mt.Kyeryong	Mt.Baekun
Species richness(R)	22	32	49	36
Species diversity(H')	0.825	0.913	1.131	1.105
Evenness(J')	0.614	0.606	0.669	0.710
Dominance(1-J')	0.386	0.394	0.331	0.290

Higher latitudinal forests in Kyunggido region were dominated by Quercus variabilis, Quercus acutissima, Quercus mongolica, Quercus dentata and Quercus aliena(Tables 2 and 3). Quercus variabilis, Quercus mongolica, Quercus serrata, Styrax japonica and Carpinus laxiflora dominated lower latitudinal forests in Chullanamdo(Table 4). However, mid-latitudinal forests in Chungchongnamdo between the above two sites were dominated by Pinus densiflora, Quercus mongolica, Quercus variablis, Quercus serrata and Carpinus laxiflora(Table 5).

Table 2. Ecological measurement for oak forests in Kwangju study area located in Kyunggido.

Species	RD	RF	RC	IV
Quercus variabilis	37.0	26.9	34.4	98.3
Quercus mongolica	12.0	15.2	7.6	34.8
Quercus acutissima	21.5	19.7	36.8	78.0
Quercus dentata	11.7	13.6	5.4	30.7
Quercus aliena	7.7	8.9	6.5	23.1
Pinus densiflora	1.6	2.6	2.5	6.7
Fraxinus rhynchophylla	1.3	2.6	1.1	5.0
Betula davurica	1.3	2.2	1.2	4.7

Table 3. Ecological measurement for oak forests in Yangpyung study area located in Kyunggido.

Species	RD	RF	RC	IV
Quercus variabilis	27.7	27.7	21.5	76.9
Quercus acutissima	30.1	22.5	18.1	70.3
Quercus mongolica	15.5	17.3	17.5	50.3
Quercus aliena	7.6	8.6	10.4	26.6
Quercus serrata	6.0	7.2	7.9	21.1
Quercus dentata	4.1	5.8	7.0	16.9
Prunus sargentii	1.2	1.9	3.2	6.3

Table 4. Ecological measurement for oak forests in Mt. Baekun study area located in Chullanamdo.

Species	RD	RF	RC	IV
Quercus variabilis	37.9	30.1	21.7	89.7
Quercus mongolica	6.9	11.9	11.7	30.5
Styrax japonica	6.8	10.3	11.7	28.8
Quercus serrata	10.5	7.8	9.4	27.7
Carpinus laxiflora	9.0	5.7	6.4	21.1
Linderaererythrocarpa	3.4	8.7	8.4	20.5
Acer mono	6.9	3.2	2.7	12.8

Table 5. Ecological measurement for oak forests in Mt. Kyeryong study area located in Chungchongnamdo.

Species	RD	RF	RC	IV
Pinus densiflora	26.8	20.2	15.4	62.4
Quercus mongolica	15.5	17.8	15.7	49.0
Quercus variabilis	17.1	16.7	14.8	48.6
Quercus serrata	9.9	6.9	8.1	24.9
Carpinus laxiflora	7.8	7.9	8.2	23.9
Castanea crenata	4.8	3.7	4.2	12.7
Styrax obassia	1.5	2.9	3.6	8.0
Prunus sargentii	2.1	2.4	3.3	7.8

Therefore, Kyunggido study areas can be classified as oak forests, Chungchongnamdo areas as pine-oak forests, and chullanamdo areas as mixed hardwood forests with oaks. In particular, the result which species dominance was shown by Quercus-Carpinus in Mt. Baekun area was similar to that reported by Park(1985).

Figure 2 shows relative density distribution of diameter class for all the species found in three study areas. In Mt. Baekun area, relative density decreased constantly as diameter at breast height increased. Many tree species appeared rather evenly at all of diameter classes, with maximum density shown at 11cm in Yangpyung area. Mt. Kyeryong area showed slow decrease in density from 8cm of diameter class as diameter increased. An inversed J-shape distribution was only shown in Mt. Baekun area which indicates more stable community rather than other areas(Begon et al., 1986).

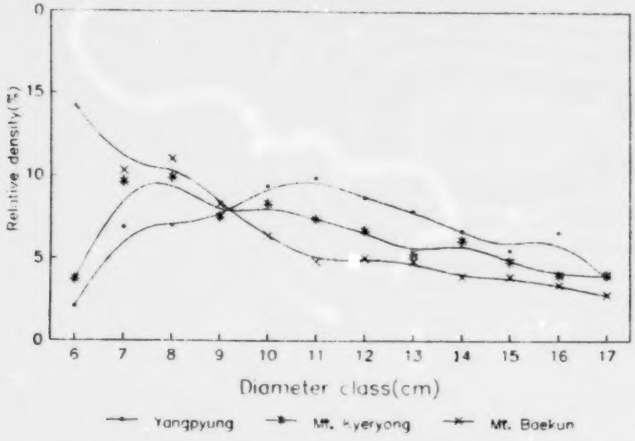

Figure 2. Relative density distribution of diameter class for total species in three study areas.

An index of diversity(H') based on Shannon-Weaver formula and evenness (J') indicated 0.825 and 0.614, respectively in Kwangju areas, and did 1.105 and 0.710 in Mt. Baekun areas(Table 1). These diversity indices were similar to those reported by Park(1985) who found 0.972 to 1.049 in Mt. Baekun sites and also to those values of 0.879 to 0.968 reported by Park et al.(1987) at Bukhansan National Park.

Positive(++, +) or negative(--, -) associations among six Quercus species growing in Kwangju and Mt.Baekun areas are shown in Figure 3. The symbols, ++ or --, indicate significance at the 1% probability level, and + or - do at the 5% level(Agnew, 1961). The positive associations between two species might indicate common habitat for two species and also grow together without antagonistic interactions.

The positive relations between Q. acutissima and Q. aliena or Q. dentata were shown in Kwangju area(Figure 3), indicating that they can grow together well. However, the negative relations between Q. acutissima and Q. variabilis were found, which may indicate different growth habitat between the two species.

In Mt. Baekun area, Q. mongolica showed highly negative associations with Q. serrata, but did highly positive one with Q. variabilis. Q. mongolica and Q. variabilis only showed positive associations in both Kwangju and Mt. Baekun areas. Other species did not have such coincidence in both areas. This reason may be due to the result that Q. serrata appeared rarely in Kwangju area, but did dominantly in Mt. Baekun area.

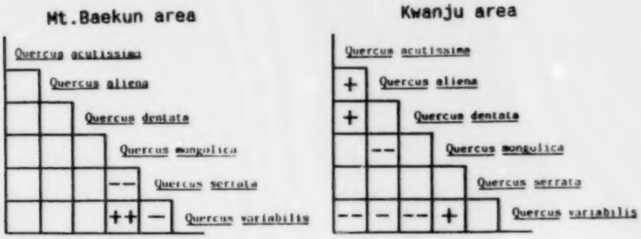

Figure 3. Chi-square matrix for six *Quercus* species in Kwangju and Mt.Baekun areas (++ and -- indicate significance at the 1% level, and + and - do at the 5% level)

Thus, further ecological stage of succession in a small-scaled forest may be also understood by the analysis of species composition(Welch, 1960).

Growth of Quercus Seedlings by Different Light Intensities

Height growth pattern of various Quercus seedlings grown under five different light conditions is shown in Figure 4. Growth increased with increasing light intensity, of which result was similar to that reported by Musselman and Gatherum(1969) who studied the growth of red oak seedlings at different light intensities.

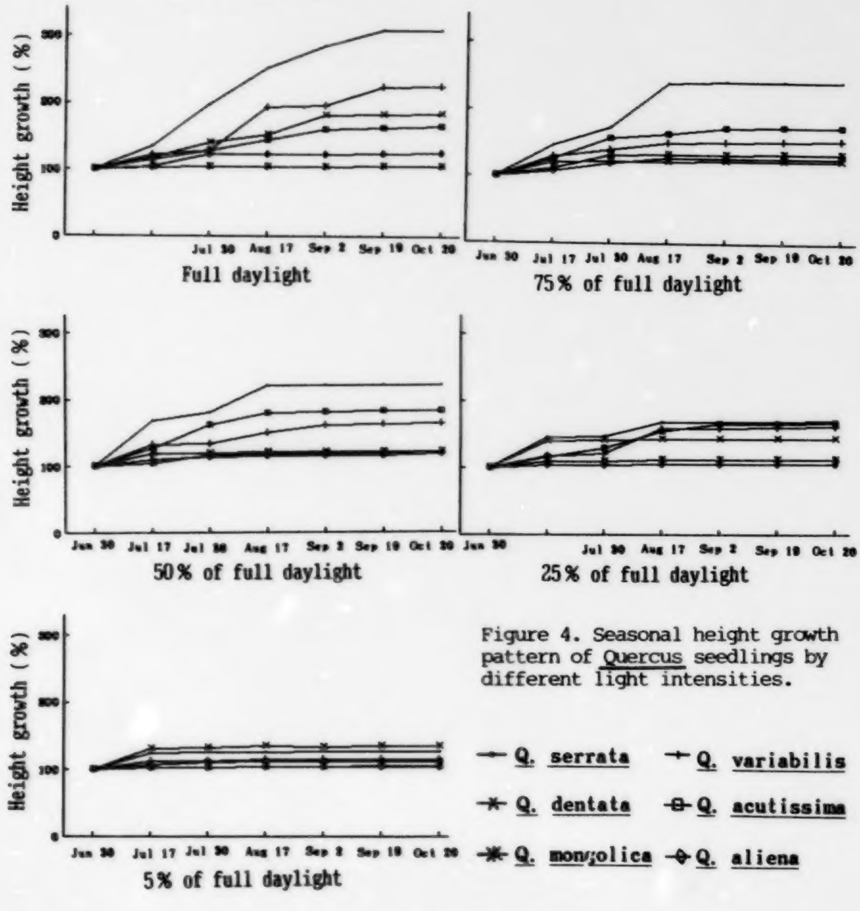

Figure 4. Seasonal height growth pattern of Quercus seedlings by different light intensities.

Although Q. acutissima showed the greatest growth in height and dry weight (Table 6), the growth rate of Q. serrata was the highest at most of the light intensities. Greatest height growth rate of Q. serrata shown at full daylight was similar to that reported by Takahara (1986) who studied the growth of Q. serrata seedling at full daylight condition.

Table 6. The height (cm) and dry weight (g) of Quercus species grown under the different light intensities at harvest time.

Species	Full daylight		75% of full daylight		50% of full daylight		25% of full daylight		5% of full daylight	
	Ht.	Dry wt.	Ht.	Dry wt.	Ht.	Dry wt.	Ht.	Dry wt.	Ht.	Dry Wt.
Q. serrata	24.7	6.96	14.9	4.41	14.5	3.49	13.4	2.58	10.0	0.77
Q. variabilis	26.1	12.27	20.0	9.20	20.0	6.91	22.3	5.11	15.0	1.57
Q. mongolica	10.9	8.70	14.5	7.42	12.2	6.25	13.6	4.94	10.9	1.66
Q. acutissima	35.0	19.48	35.7	17.54	39.1	12.04	36.2	9.73	21.8	3.33
Q. dentata	15.9	9.52	12.8	4.81	10.9	3.81	15.8	4.58	14.3	2.07
Q. aliena	18.1	14.81	20.3	13.24	14.9	6.91	15.5	5.18	14.8	2.60

Figure 5 indicates dry weight distribution of Quercus seedlings to each of the growth organs by different light intensities. Dry weights were distributed mostly to roots in most of the species. However, the least dry weight of roots was shown at the 5% of full daylight. Increase pattern in dry weight growth with increasing light intensity was also similar to the result reported by Musselman and Gatherum (1969).

Regeneration of Quercus Species from Seed and Sprout

The acorns remained and germinated in Q. acutissima and Q. mongolica stands and at clearcut sites after seeding are shown in Table 7. Q. acutissima showed better seed germination than Q. mongolica both within stands and at clearcut sites. Both of these species exhibited better regeneration at the treatments of wire net cover, nylon net cover or mulching than at control or scratching treatments. However, there were no differences in regeneration of both species between two sites.

Table 7. The percentage of acorns remained and germinated after seeding in Q. acutissima and Q. mongolica stands and at clearcut sites.

Treatment	Quercus acutissima		Quercus mongolica	
	Within stand	Clearcut site	Within stand	Clearcut site
Wire net	35.0(12.5)*	37.5(18.5)	43.5(9.5)	37.5(12.5)
Nylon net	52.5(22.5)	31.5(22.5)	44.0(5.0)	35.0(9.5)
Mulching	22.5(22.0)	33.5(13.5)	10.0(1.0)	25.0(6.5)
Scratching	7.5(2.5)	8.5(2.5)	1.0(0.0)	3.5(0.0)
Control	10.0(0.0)	15.0(2.5)	12.5(0.0	2.0(0.0)

* The numbers in parenthesis indicate the percentage of acorns germinated.

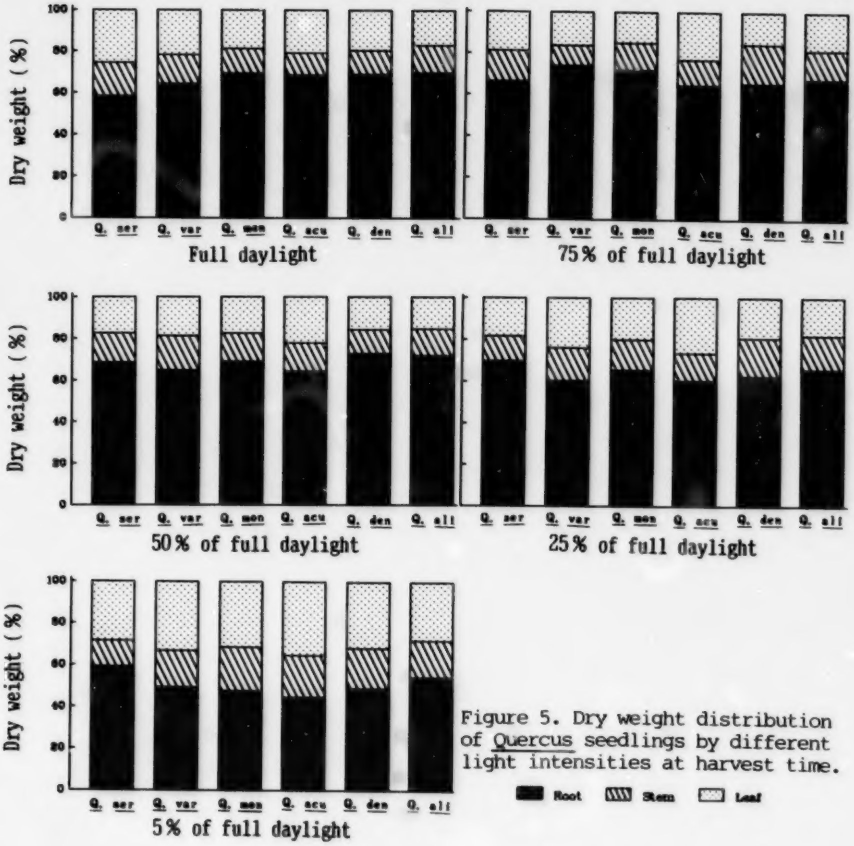

Figure 5. Dry weight distribution of Quercus seedlings by different light intensities at harvest time.

In general, seed germination was rather poor at all of the treatments and at both sites for all of the species. This result may be explained by biotic factors such as several birds, mammals and insect larvae eating acorns(Kanazawa, 1975).

Therefore, it is concluded that at least such treatments as covering or mulching over acorns seeded help better regeneration of Quercus species.

The sprout growth of Q. dentata and Q. mongolica after stump-cutting is shown in Tables 8 and 9. The sprouts of two oak species grew well, but the growth of sprouts, in general, was more vigorous for Q. mongolica than for Q. dentata. The number of sprouts, and sprout length and dry weight increased with increasing diameter of stumps up to about 30cm in both species. The result of the sprout number related closely to stump diameter was different from that of Sato et al.(1966) who found that there were no relations between the number of sprouts and stump diameter size in Q. serrata. Thus, sprouting may be useful for reproducing Quercus species.

Table 8. The sprout growth after clearcutting at *Q. dentata* stand located in Jeongseon-gun, Kangwon-do.

Dia.of stump (cm)	No.of sprout sites	No.of sprouts	Length of sprout (cm)	Dia.of sprout (mm)	Dry weight of sprout (g)
3.9- 9.4	4	10	58	9.4	98
11.5-19.5	6	20	78	18.3	358
20.1-29.0	6	33	87	13.2	512
31.0-36.6	3	17	96	16.9	455

Table 9. The sprout growth after clearcutting at *Q. mongolica* stand located in Jeongseon-gun, Kangwon-do.

Dia. of stump (cm)	NO.of sprout sites	No.of sprouts	Length of sprout (cm)	Dia. of sprout (mm)	Dry weight of sprout (g)
5.8- 8.2	8	18	90	8.8	198
12.1-17.0	12	33	127	15.6	698
20.4-28.5	7	28	128	14.4	664
30.2-38.6	8	32	142	15.0	1510
41.0-54.0	6	47	147	14.4	1143

CONCLUSION

All the study areas were dominated by *Quercus* species. However, species composition becomes diverse with decreasing latitude. High latitudinal areas in Kyunggido are characterized as oak forests, low latitudinal areas in Chullanamdo as mixed hardwood forests with oaks, and mid-latitudinal areas in Chungchongnamdo as pine-oak forests.

Quercus mongolica showed highly positive associations with *Q. variabilis*, but did rather negtive ones with *Q. serrata.*

Q. serrata was the best in growth rate of height and dry weight under most of the light intensities. Much dry weights were distributed to roots at all the intensities for all the species.

Covering or mulching over the seeded acorns helped better regeneration of oaks. Sprouting is useful for reproducing *Q. mongolica* and *Q. dentata.*

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A MULTI-RESOURCE SILVICULTURAL DECISION MODEL FOR FORESTS OF THE NORTHEASTERN UNITED STATES[1]

David A. Marquis

Principal Research Silviculturist

U. S. Department of Agriculture Forest Service
Northeastern Forest Experiment Station
Warren, PA, USA

FDC: 62: 916--01: (73)

SUMMARY

A computerized decision model is under development for forests of the northeastern United States. The model will provide expert support for land managers charged with developing silvicultural prescriptions to achieve a wide variety of timber, wildlife, and esthetic goals. Data on forest vegetation, site conditions, and management objectives is the basis for management recommendations generated by the program. These recommendations are based on knowledge and guidelines accumulated from many years of research on all major forest types throughout the region. In addition to generating an expert opinion on each stand, users may compare the recommended treatment and other alternatives through the stand growth simulators incorporated into the program. The comparisons can include analysis of economic returns and effects on forest stand development, wildlife habitat suitability, and visual conditions.

Keywords: silvicultural systems, multiple-use, computer models

INTRODUCTION

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[1] The NE Decision Model is being developed by a team of scientists from twelve Northeastern Forest Experiment Station work units, plus colleagues from the Eastern Region of the National Forest System, the Northeastern Area State and Private Forestry, and the North Central Forest Experiment Station.

Forests in the northeastern United States are used for a variety of purposes, including timber production, wildlife habitat, and all types of outdoor recreation. Although in the past timber management was often the primary goal of forest management, other resource uses have become increasingly important. For many woodland owners, timber production is much less important than wildlife and recreational use of their land. Even those who hold land primarily for timber production usually attempt to integrate other resource uses into their management.

Research has provided a large amount of sophisticated information on forest management for these uses, but the information is scattered and difficult to apply across the many forest types in the region. Further, much of the information applies to a single resource use. Guidelines for integration of available knowledge for true multi-resource management are limited.

There are, for example, sophisticated silvicultural guides available for timber production of many of the commercially important forest types of the Northeast. These include guides and major summaries prepared for spruce-fir (Frank and Bjorkbom 1973), northern hardwoods (Leak et al 1987, Nyland 1987), paper birch (Safford 1983), Allegheny hardwoods (Marquis et al 1984), oak-hickory (Roach and Gingrich 1968), and Appalachian hardwoods (Smith and Eye 1986, Smith et al 1988). Others include those for stand management in the presence of severe disease or insect problems such as the gypsy moth (Gansner et al 1987, Gottschalk 1986). Numerous stand growth simulators are also available for northeastern forests. They include: NE-TWIGS for various forest types (Hilt and Teck 1988), SILVAH for Allegheny hardwoods (Marquis 1986), OAKSIM for oak-hickory (Hilt 1985a, 1985b), FIBER for spruce-fir and northern hardwoods of New England (Solomon et al 1987), and GRO2 for New England forests (Sendak 1985).

Considerable information is available on harvesting methods and their impact on silviculture and management economics (LeDoux 1986, 1988; Reisenger et al 1988), and on the general economics of timber value changes (DeBald and Mendel 1976, Mendel et al 1976). Computer models that facilitate economic analyses of timber investment opportunities are readily available (Brooks et al 1984), including such programs as TWIGS (Blinn et al 1988), and MS-YIELD (Hepp 1988).

Specific guidelines on the management of forests for wildlife and esthetics are not as well developed as those for timber production, although there is a considerable body of knowledge on these subjects, as well as much current research. Detailed information on wildlife species in New England has been compiled (DeGraaf and Rudis 1986), and general guidelines for management of wildlife trees and cavity trees are now available (DeGraaf and Shigo 1985, Tubbs et al 1987). Models to evaluate habitat suitability are also available for many wildlife species, such as

the HEP models developed by the U. S. Department of the Interior Fish and Wildlife Service (Schamberger and Farmer 1978, U. S. Department of the Interior Fish and Wildlife Service 1981). General guidelines on landscape management practices suitable to meet various visual goals are also available (U. S. Department of Agriculture Forest Service 1980).

Considerable information is available on individual aspects of integrated forest management for multiple resources. Some examples include selection and retention of wildlife trees in relation to timber production (Tubbs et al 1987) and the distribution of harvest cuttings to meet the needs of both timber and deer (Roach 1974). Models designed to assist in forest-wide integration of multiple resource planning have also been developed, such as the DYNAST-MB model (Boyce 1977, Boyce and Cost 1978).

These information sources provide important knowledge for integrated resource management. The information, though, is scattered and incomplete. Site-specific guides for individual stands and larger forest units are not available. To meet these needs, the Northeastern Forest Experiment Station U. S. Department of Agriculture, Forest Service, is developing a computerized multiple-use decision model (NE Decision Model) for the northeastern United States. The model will incorporate information on silviculture, growth and yield, harvesting, economics, wildlife habitat management, landscape architecture, and insect and disease management.

The primary goal of the NE Decision Model is to provide expert recommendations to optimize multiple-use management in all major forest types and regions of the northeastern United States. Recommendations will be based on management goals specified by the user, along with data on site and vegetation in the stand and surrounding forest. A secondary goal of the model is to provide the ability to test the effects of alternative management strategies on timber yields, wildlife habitat, and esthetics. To accomplish this function, the NE Decision Model will include stand growth simulators appropriate to northeastern forests.

Development of the model will entail the consolidation of existing knowledge, making it more accessible to users. It will also provide direction for future research by exposing gaps in the existing knowledge, and by highlighting conflicts among resource uses. The structure and function of the NE Decision Model is described in this paper.

NE DECISION MODEL

Expert Recommendations

The first and most important function of the NE Decision Model is to provide expert opinion on multi-resource management for the important forest types in the Northeast. Recommendations, or prescriptions, are to be specific to individual stands managed for a particular set of management goals.

For example, an expert recommendation for an aspen stand being managed for grouse habitat might call for an even-age silvicultural system with the current treatment being a harvest cut to provide an area of dense young aspen stems for food and cover. Or, an expert recommendation for a small sawtimber-size cherry-maple stand being managed for timber production and wildlife diversity might call for an even-age silvicultural system with the current treatment being a commercial thinning with retention of specific types and numbers of trees for high-quality sawtimber and veneer production, plus retention of specific types and numbers of trees for wildlife dens and mast production. In each case, the recommendations would include detailed information on the current treatment in that particular stand.

The recommendations for each stand will include two components: the silvicultural system to be used over the long term, and the current treatment. The silvicultural system will be selected on the basis of management goals and forest type. Current treatments within that system will be selected on the basis of current vegetation and site conditions in the selected stand and in the surrounding area. The recommended treatments will organize the vegetation within a group of stands managed together (a compartment) in order to achieve the optimum distribution of species, stand sizes, and stand structures over both time and space.

The initial data entered into the program will be the management objectives for a group of stands. As currently formulated, the NE Decision Model will incorporate four timber management goals, six wildlife management goals, and four esthetic goals; a total of 96 combinations for any forest type. These goals are

Timber:

1) no timber management
2) recovery of management-ownership costs
3) maximum fiber production
4) maximum timber value production

Wildlife:

1) no wildlife management
2) maximum species diversity
3) optimum density of early-succession wildlife species (specific species are selected from a group of both game and non-game species representative of a wide range of guilds and habitat types. The following species will be included: white-tailed deer, ruffed grouse, snowshoe hare, chestnut-sided warbler, eastern bluebirds, gray squirrel, black bear, pileated woodpecker, wood thrush, flying squirrel, masked shrew, barred owl, and wild turkey. Other species may be added later.)
4) optimum density of late-succession wildlife species (specific species are selected, as described above)
5) optimum density of mixed wildlife species
6) combination of diversity and density of selected species

Esthetic:

1) no esthetic management
2) maintenance of variety in density, size, and type of vegetation. Even-age silviculture is acceptable if final harvest cuts occur over several entries and involve well-established sapling regeneration before the final overstory removal is completed.
3) high forest cover at all times
4) large-tree visual appearance with high forest cover at all times

The NE Decision Model will recognize ten forest types, including: 1) beech-birch-maple, 2) cherry-maple (Allegheny hardwoods), 3) cove hardwoods (Appalachian hardwoods), 4) northern hardwood/oak (beech-birch-maple/oak-hickory), 5) oak-hickory, 6) aspen-birch, 7) white pine, 8) pine/hardwood (white pine/beech-birch-maple), 9) spruce-fir, 10) mixed wood (spruce-fir/beech-birch-maple). See Table 1 for scientific names of tree species included in these forest types. With 96 combinations of management objectives, and 10 forest types, there are 960 possible combinations.

There are six major silvicultural systems recognized in the model: 1) no cutting; 2) uneven-age silviculture with single-tree selection only; 3) uneven-age silviculture with a combination of single-tree and either true group selection or small-patch clearcutting; 4) two-age silviculture; 5) even-age silviculture with no clearcutting; and 6) even-age silviculture with all traditional even-age harvest methods. Many variations in cutting cycles, stand stocking and structure, and other parameters are required to meet the full range of management objectives. In addition, there are numerous special treatments, including retention of particular kinds and numbers of trees or stands for

wildlife and visual purposes, and removal of particular kinds of vegetation with herbicides or other measures.

The model will select the silvicultural system to be applied in all stands of the compartment, using a series of decision charts developed by a team of natural resource professionals from all branches of the U. S. Forest Service working in the Northeast. To develop these charts, the team selected the overall silvicultural system recommended to meet the management goals for each forest type. Then, appropriate treatments to be applied at various stages in stand development were outlined within each silvicultural system - management goal - forest type combination.

The process begins by selecting a silvicultural system for the compartment. Data on the individual stands within the compartment and the management goals for the compartment are entered into the model. Stand data will come from a systematic, multi-resource inventory, and will include information on site, topographic factors, and overstory and understory vegetation. The data will be summarized to show a variety of important characteristics of each stand which include: forest type, species composition, density and size class of the overstory, understory density, species composition and height, interfering plant presence and density, and similar parameters. Summary information will be stored in a geographic information system for compartment-level processing.

Current treatment recommendations are then generated for each stand individually. Using the stand summary data described above, the model analyzes that data to determine the potential of each stand for regeneration, timber growth and yield, suitability as habitat for selected wildlife species, and ability to meet various visual quality goals. Each stand is considered as a separate entity, and a preliminary current treatment is developed without regard to treatments that may be applied in surrounding stands. The prescriptions are based on the individual stand's stage of development relative to the silvicultural system selected previously.

When preliminary treatment recommendations have been developed for all stands in the compartment, a compartment-level routine will reconcile the desired distribution of vegetative types with the individual stand treatments (and with surrounding vegetative areas not being managed within the compartment). Thus, if the individual stand treatments provide too much or too little of a particular vegetative condition to meet the management objectives, the individual stand treatments will be modified accordingly. Desired distribution of vegetation is based on sustained yield and even-flow principles, and is an inherent part of the overall silvicultural system.

When current treatments need modification to meet compartment-level requirements, the most suitable stands are selected. For example, if additional stands are selected for harvest cutting to meet timber regulation needs or to provide adequate well-distributed, early-successional vegetation, the stands most appropriate to receive a harvest prescription will be selected.

Alternative Testing

A second major objective of the NE Decision Model is to permit alternative testing. While the model will provide expert opinions appropriate to common situations, there will often be a need to do "what if?" analyses. Unusual circumstances may cause this to be desirable for specific stands, and management planning exercises may require quantitative comparisons from which to select a desired management alternative.

The NE Decision Model will provide several levels of alternative testing. In its simplest form, the model will allow the user to select from a wide range of possible treatments, and to compare the immediate effect (after treatment or after cutting) on parameters such as timber volumes and values, stand density, size, quality, and species composition, and wildlife habitat for any of the included species and visual impacts. Evaluations of these immediate effects will often be important in deciding whether to use a particular treatment, or to modify a recommended treatment in individual stands and compartments.

A more complex form of alternative testing will involve the projection of stand growth, mortality, and regeneration, permitting long-term comparisons among management strategies. Several existing stand growth simulators will be built into the model, and the model automatically will select the simulator most accurate in that forest type and geographic region. The stands projected by the simulators can then be re-analyzed to determine their value for timber, wildlife habitat, and visual purposes just as was done with the original stand data.

Economic analysis routines included in the model will permit automatic recording of costs and returns over the simulation period and will perform several common types of economic analyses for timber production. Wildlife and visual effects will also be tracked over time, providing a measure of the long-term results of management on those resources.

To facilitate the use of several simulators, the NE Decision Model will provide a single data input format. That input data will be converted to the form needed by each simulator. The simulators will be used only to predict future stand development; projected tree numbers and sizes will be reconverted into the

standard format for data summaries and analysis. Thus, all stand parameters (such as volumes, values, stocking,) will be calculated by the main program in a standard way, making outputs comparable regardless of the simulator used.

Model Structure

The overall model structure will consist of six major components (Figure 1). The input data in the form of a tree list, understory counts, and site information, will be sent to a core module for processing. This central core module will control the flow of data through the stand analysis, prescription, and prediction modules, and will access input and output routines. The prescription module will utilize the summaries and results of the stand analysis module to develop a recommended treatment. If desired, the user may then pass the data to the prediction module where either the recommended treatment, or alternatives may be projected and the results analyzed.

Work on the NE Decision Model is well under way. Teams of scientists throughout the Northeast are organizing the existing information and are developing algorithms to accomplish the model's tasks. Two programmers are writing the source code for the computer program itself. Plans are to complete a first version by 1992, and to have it tested and available for use by early 1993.

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Figure 1. NE Model Structure.

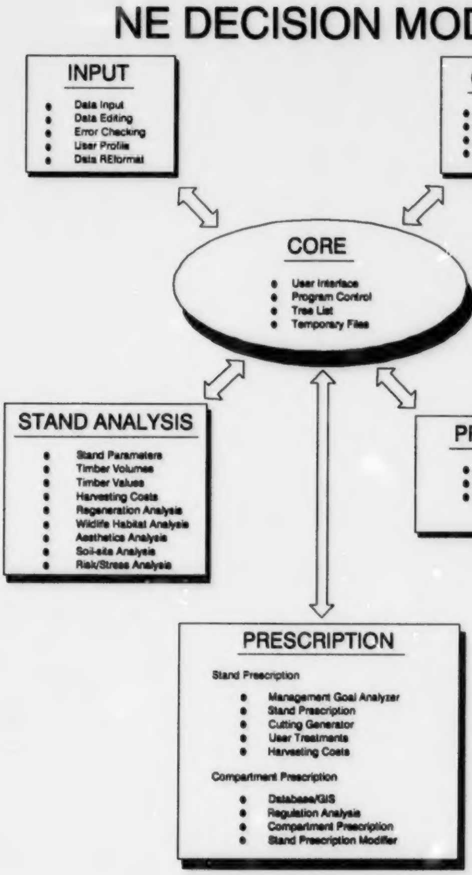

Table 1. Common and Scientific Names of Tree Species.

beech-birch-maple type
American beech -- *Fagus grandifolia*
yellow birch -- *Betula alleghaniensis*
sugar maple -- *Acer saccharum*

cherry-maple type
black cherry -- *Prunus serotina*
sugar maple -- *Acer saccharum*
red maple -- *Acer rubrum*

oak-hickory type
northern red oak -- *Quercus rubra*
scarlet oak -- *Quercus coccinea*
black oak -- *Quercus velutina*
white oak -- *Quercus alba*
chestnut oak -- *Quercus prinus*
hickory -- *Carya spp.*

aspen-birch type
quaking aspen -- *Populus tremuloides*
big-tooth aspen -- *Populus grandidentata*
paper birch -- *Betula papyrifera*

white pine type
eastern white pine -- *Pinus strobus*

spruce-fir type
red spruce -- *Picea rubens*
balsam fir -- *Abies balsamea*

MANAGING AND PROTECTING FORESTED WETLANDS

Juhani Päivänen
Dept. Peatland Forestry
University of Helsinki
Helsinki, Finland

and

Eero Paavilainen
Dept Peatland Forestry
Finnish For. Res. Institute
Helsinki, Finland

FDC: 237.2: 114.444: 62

SUMMARY

The enormous area of wetlands has a great potential for forestry. Forest amelioration in waterlogged areas is part of the normal forestry practices in Fenno-Scandinavia, the Soviet Union, the British Isles and in some parts of the USA. In Canada there are experiments going on, but forest drainage in practice is still scanty. It is estimated that currently only about 14 million hectares of peatlands and wetlands have been drained for forestry in the boreal and temperate zones. More than 90 per cent of this is situated in the Fenno-Scandinavian countries and the Soviet Union. In connection with amelioration activities the environmental aspects have to be considered. More research is needed to promote the use and protection of wetland forests in the tropics.

Keywords: Mires, wetlands, peatland forestry

INTRODUCTION

Especially in the northern boreal region, but also in the temperate and tropical areas, there are plenty on forests whose use for wood production is hampered or completely prevented by excessive wetness. A majority of these are peatlands.

According to an even conservative estimation over 14 million hectares of waterlogged peatlands and mineral soil sites have been taken into the sphere of forestry by draining and also fertilizing, if necessary. The continuous wood production is secured by arranging the water and nutrient conditions and by regenerating the sites either naturally or artificially after

the final felling. There are in the world also, however, plenty of waterlogged forest areas that are harvested without arranging the water conditions or without other forest improvement measures.

It is important that there are enough peatlands and other waterlogged forest lands protected for research, preservation of rare plant and animal species as well as for recreational activities. Therefore some countries have prepared a special protection programme for their peatlands and wetlands.

It is difficult to get a reliable overall picture of the use and protection of waterlogged forest land in different parts of the world on the basis of available information that is scarce and inaccurate. This report will discuss the question in the light of a few examples that are based on literature, the authors' own experiences as well as on the answers to our questionnaire.

STATE-OF-THE-ART - AREAL EXAMPLES

F e n n o - S c a n d i n a v i a

The most extensive use of waterlogged areas for forestry in Fenno-Scandinavia is in Finland. According to the 3rd National Forest Inventory (1951-53) there were about 9.7 million hectares of peatland and about 1.4 million hectares of paludified mineral soil sites in Finland. The area of peatland drained for forestry was over 5.7 million hectares at the end of 1986. The total target of drainage is 6.5 million hectares, which will probably be attained by the turn of the century. The annual new drainage area, which was 300,000 hectares at its most, is only 40,000 hectares now.

In Sweden the area of peatland is about 7.8 million hectares. It is estimated that 4.3 million hectares would be potentially suitable for forestry, but less in practice i.e. 3.0 million hectares (Holmen 1968). At the end of 1986 the area of peatland drained for forestry was about 1.2 million hectares, the annual drainage area being about 20,000 hectares in the 1980s.

In Norway the peatland area below the tree line is about 1.8 million hectares and that of waterlogged mineral soils 0.4 million hectares. It is estimated that by merely draining 0.3 million hectares could be brought within the sphere of forestry, and an additional 0.4 - 0.5 million hectares by also fertilizing (Jerven and Wisth 1967). At the end of 1988 the area of forest drainage was 0.4 million hectares and the annual drainage area about 5,000 hectares. The aim is, however, to increase the annual drainage area to 15,000 hectares.

As systematic forest drainage has been practised in these countries for decades, the classification of drainability, fertilization and silvicultural methods as well as the drainage

technique are fairly advanced. The classification of peatlands for forestry is primarily based on peatland flora, although, especially in old drainage areas, chemical soil and foliar analyses are often useful.

The depth of ditches depends on the site. Deep ditches (> 0.8 m) are used on wet deep-peat mires where peat subsidence is heavy. On paludified mineral sites the ditches may be less than 0.7 m deep. the biologically optimum drainage density is higher (330-400 m/ha) on oligotrophic deep-peat mires than on fertile minerotrophic ones, shallow-peat mires and paludified mineral soil sites (200-250 m/ha).

Hydraulic tractor diggers and excavators are most commonly used on forest-growing mires and ploughing and mounding in connection with afforestation, in which case planting takes place on turned peat.

Fertilization with phosphorus and potassium improves the growth of the stand, except on the most fertile peatland types, the time of influence being usually 10-15 years. Nitrogen in addition to PK fertilization is needed on oligotrophic mires. In such conditions the influence of nitrogen lasts for less than 10 years. A boron shortage has been observed in the stands in drainage areas, which is why this nutrient is usually applied at fertilization.

There are only few economically important tree species in Fenno-Scandinavian drainage areas: spruce (Picea abies), pine (Pinus sylvestris) and birch (Betula pubescens and B. pendula), and also Sitka spruce (Picea sitchensis) as an exotic one in Norway. The biggest problem in forest management is a large number of middle-aged stands, birch colonization typical of drainage areas and difficulties in the regeneration of old drainage areas.

The forest ecosystem of drainage areas, brought on by forest improvement measures, may without management easily change unfavourably from wood production point of view. Therefore, ditches need maintenance, the nutritional imbalances must be corrected by fertilization and the forests must be tended. Thus drainage activities continue after the first drainage as large-scale improvement drainage is needed. According to the lates Forest 2000 project, planned in Finland, the need for maintenance of drainage areas is annually 120,000 hectares in the late 1980s. Actually the annual extent of ditch cleaning and supplementary ditching is, however, only 50,000 hectares.

An idea of the post-drainage growth of peatland stands can be received from the results of the 7th National Forest Inventory (1977-84) in Finland. The total increase in tree growth brought on by drainage, fertilization and good forest management on waterlogged forest land exceeded 7 million m^3 in Finland at the beginning of the 1980s and it is expected to rise to 15 million

m^3 by the turn of the century (Heikurainen 1982, Paavilainen and Tiihonen 1988).

As the forest drainage has extended, more attention has been paid to environmental aspects. Efforts are made to prevent sludge and humus from being carried to waterways by building special discharge basins, discontinued ditches etc. By correctly choosing the fertilization time and technique nutrients are prevented from being carried away from the drainage area, etc.

In all Fenno-Scandinavian countries some peatlands are protected from economic use in order to preserve the natural flora and fauna and in general the versatility of nature. In Finland the nationwide protection programme includes 610 protection areas with a total of 498,000 hectares, in other words 5 % of the original peatland ecosystem in the country. In addition, about 200,000 hectares of protected peatland areas are located in Nature and National Parks.

The Soviet Union

An estimated 245 million hectares of peatland and waterlogged forest land are found in the Soviet Union (Sabo 1988). The area suitable for forest drainage is 37.6 million hectares, 22.5 million hectares of which are in the European Soviet Union, 11.4 million hectares in the Ural-West Siberian region and 3.7 million hectares in the Far East. The forest drainage activity started as early as the 1800s. To date about 6 million hectares have been drained, the annual drainage area being 180,000 - 200,000 hectares (Vompersky 1989).

The above-mentioned parts of the Soviet Union differ from one another in their main goal settings in forest drainage. In Europe, especially in the northwestern parts and the Volga-Vjatski area, forest drainage is primarily both an economic measure and an effort to satisfy the requirements of wood industry. The aim in the Ural-West Siberia is not only increased wood production, but also the creation of green zones around developing industrial and agricultural centres. In the Far East the primary aim with forest drainage is to protect the agricultural areas near large population centres.

Heavy forest drainage machinery, usually excavators, are widely used for forest drainage in the Soviet Union. The ditches are larger than in Fenno-Scandinavia. The continental climate and peat quality are some of the reasons for the widely spaced ditch networks (50-150 m/ha). Intermediate cuttings are few and the use of fertilizers is small except within the versatile experimental activities.

According to Sabo (1988) forest drainage has increased the wood resources of peatland forests by 110 million m^3 in the

Soviet Union. An important future measure will be the development of the ditch cleaning mechanization for conditions without ditch shoulders.

It is considered important already at the planning stage to take into account the possible consequences of drainage, e.g. in the stand growth of the surrounding mineral sites and the multiple use of peatland areas. The most recent peatland protection programme involves 1,600 areas with a total of 4 million hectares (Botch and Masing 1983).

The British Isles

The total peatland area in Great Britain and Ireland is 2.7 million hectares (Taylor 1983).

In Scotland peatlands are divided into two groups as to their origin. In North and West Scotland and partly in the central highlands they have been formed as a result of abundant rainfall, low mean tenperatures and high relative air humidity. In these areas ombrotrophic blanket bogs dominate. Topogenous mires form the other group of peatlands. These are usually soligenous by origin and are located in mineral soil depressions or they have originated through overgrowing of water ponds. In their present form they may be over 10 metres deep. The subpeat is usually mesotrophic and the surface peat oligotrophic raised bog peat, mainly formed of cotton grass, Sphagnum fuscum and Calluna (Robertson 1968). There is a special mire and peat classification for the needs of forestry (see Toleman 1973). Scotland has an estimated 810,000 hectares, i.e. more than 10 % of the land area, of more than 30-cm-deep peatlands (Robertson 1968).

Drainage, usually in combination with soil preparation, is a conventional measure connected with afforestation. The feeder drains are 90 cm deep. On deep-peat mires 60-cm-deep surface-water furrows are usually ploughed parallel with feeder drains with double moulboard ploughs. Exotic tree species are used in plantations. The most commonly used species are Picea sitchensis and Pinus contorta.

The two other important peatland forestry regions are the Republic of Ireland and Northern Ireland. In the former there are about 170,000 ha (van Eck et al. 1984) and in the later about 80,000 ha (Taylor 1983) planted forests on drained peatlands.

It can be estimated that there are altogether about 800,000 ha of man-made forests on drained peatlands and wetlands in Great Britain and Ireland.

U S A

There are plenty of peatlands ranging the Lake States to the Atlantic Ocean in the United States. Peatlands are mainly ombrotrophic raised bogs which display variation caused by the continental-marine gradient. The effect of forest drainage on the water conditions or growth of stands has not been much studied. Hydrological research have focused on the various uses of peatlands that would increase low discharge and protect the water quality.

In the Lake States the so-called prescription-type drainage has been practized on poorly drained mineral soil sites. This means a low-intensity ditch system with which the natural drainage ways are opened and the locally high water table controlled. The water table can be affected at distances in excess of 300 m from the ditch. As a result the area concerned will be a non-wetland type following drainage (Trettin et al. 1989).

In the southeastern states two groups of peatlands and wetlands can be distinguished: Bottomlands and swamps are overflow wetlands on which clearcutting and natural regeneration of decidious species are practized. Flatwoods and pocosins are broad flat areas that have poor surface drainage and include both mineral and peat soils. These wetland types are well suited to pine plantations after drainage. Until now about 400,000 hectares of wetlands have been drained for forestry. In the southeast term "water management" including both drainage, water level control, site preparation and fertilization is preferred (Gregory 1989).

In the mountain areas of the United States there are also some topogenous mires but their utilization for forestry has not been reported.

C a n a d a

Over 80 % of the Canadian forest land belong to the northern boreal coniferous forest belt which reaches from Yukon to Newfoundland. In this cool and humid climate there are plenty of mires. A rough estimate is that peatlands account for about 110 million hectares i.e. about 12 % of the total land area (Pollett and Tarnocai 1983, Tarnocai 1984). The estimate included peatlands with over 40-cm-deep peat (Zoltai and Pollett 1983). It is estimated that there are 170 million hectares of wetlands in Canada (Zoltai and Pollett 1983). This figure includes also areas where the ground water level is near the soil surface or even above it when the ground is unfrozen. It has also been suggested that the peatland area has been considerably underestimated. Furthermore, for Canada as a whole, there are

no figures that quantify the extent of forested mires or productive forest land on organic substrates (Haavisto and Jeglum 1989).

Due to the size of Canada and the resultant diversity in geography, soils and climate, the mire complex types and site types and the potential for forest production can be very different. Haavisto and Jeglum (1989) have recently given a province-by-province estimation of the mire area and a summary of forestry activities on peatland. According to this review and the interviewed experts the authors of the present paper have reached the conclusion that by the end of the year 1989 only a total of 20,000 hectare of forest drainage have been carried out in Canada. Thus the 100,000-hectare estimate by Kivinen and Pakarinen (1981) was obviously too optimistic.

The interest on forest drainage differs from one province to another. Small-scale experimental activity in forest drainage has been carried out in Newfoundland, New Brunswick and Nova Scotia. In an operational experimental scale, forest have been drained in Alberta and Ontario, a little over 1,000 hectares in both (Haavisto and Jeglum 1989). The Quebec province has a short but intensive history of forest drainage. During the past three years 4, - 5,000 hectares per year have been drained mainly in clearcut areas (Trottier 1989). In both of the last mentioned provinces forest drainage manuals have been compiled (Guide...1989, Rosen 1989).

However, the forest drainage areas alone give a misleading idea of the utilization of peatlands for forestry in Canada. An example is Ontario where about 20 % of wood is harvested from black spruce-dominated peatlands. The ground water level rises as a result of cuttings and forest drainage could apparently promote the development of naturally regenerating stands. Also the harvesting methods should be developed so that the advance growth typical of the overmature black spruce stands could restock the area after harvesting.

People's Republic of China

It is estimated that there are about 10 million hectares of wetland forests, 3.5 million hectares of which are actual peatlands, in the People's Republic of China. Peatlands are located mainly in the northern and northeastern parts of the country and on the Qing Zhang plateau. A third of the peatland area is in Northeast China (Zhao and Päivänen 1986). The best possibilities for the forestry use of peatlands is in the Xingan and Changbai mountains where, according to some estimates, there are over 1 million hectares of peatland suitable for drainage and afforestation (Liu and Zhao 1987).

There is not as yet a nation-wide classification for demonstrating the drainability of peatland for forestry, although various classifications have been made for different scientific purposes. As for their forestry use treeless peatlands are divided into two main groups according to the water conditions of the site and the technical drainability of the site: peatlands waterlogged for part of the year (June-August) and those waterlogged for the whole year (Kaunisto 1982).

The primary aim of drainage is to occupy wasteland for forestry and thus increase the area of forest land. Therefore forest-growing peatlands have remained undrained, while the focus of drainage is solely on open peatlands. It has been estimated that there is a total of 67,000 hectares of peatlands drained for forestry in China.

It would be justified to extend the present research and experimental activities also on forest-growing peatlands. It would be particularly important to develop the site type classification for the estimation of the wood production capacity on both open and forest-growing peatlands.

As the economic utilization of peatlands increases, more attention has been paid to peatland protection as well. In 1982 two large (several tens of thousands of hectares) peatland protection areas were established on the Sanjiang plain (Zhao and Päivänen 1986).

Southeast Asia

Southeast Asia is a good example of the forestry use of wetlands in the tropics. There, as well as in various places in South-America and Africa, are large peatland areas as well as other forest areas that are constantly or for part of the year waterlogged. Indonesia is estimated to have roughly 26 million hectares of peatland, most of which are in eastern Sumatra and southern Kalimantan (Driessen and Soepraptohardjo 1974). Malesia and Brunei are covered with 2.4 million hectares of peatlands (Andriesse 1974). There are some peatlands also in Thailand and the Philippines.

Peatlands are mainly situated in lowlying coastal areas and deltas where the tide continually changes the water level. The variation in the water level is further affected by frequent rains typical of the tropical forests and on the other hand dry seasons when the ground vegetation may become scorched and vulnerable to fires.

The most important tree species in the Indonesian and East Malesian peatlands is Gonystylus bancanus used in sawmill industry. Also the Shorea species have commercial value.

Harvesting is mainly carried out as dimension fellings and the regeneration of forests is mostly neglected.

To date it is very little known what kind of water conditions would lead to the best growth and be the most beneficial from the regeneration point of view in tropical peatland forests. If an effective drainage is the aim, these level peatland areas pose a difficult problem. Maintaining the variation in the water level at its minimum would require a damming system and possibilities for regulation. The arrangement of the water conditions presupposes the solving of many technical-economic problems in these conditions.

A further problem is difficult communications. The road and railway networks are nearly non-existent in these reagions, and often the use of the waterways has its own problems as well.

A sustainable forestry use of the waterlogged areas in Southeast Asia presupposes the creation of a site type classification and the development of the management of natural forests so that the post-harvesting regeneration is successful. Furthermore, experimenting with fast-growing tree species on peatland should be started in the most suitable areas in order to satisfy the needs of the pulp industry. The need for protecting natural forests should also be studied. Plenty of research and experiments are still needed for planning the continuous use of peatland forests.

DISCUSSION

The above-described examples show that forest amelioration activities in waterlogged areas are part of the normal forestry practices in Fenno-Scandinavia, the Soviet Union, the British Isles and in some parts of the USA. In Canada, the Lake States of the USA and China there are experiments going on, but forest drainage in practice is still scanty. The need for new research and experiments seems to be most urgent in the waterlogged areas of Southeast Asia where there is very little activities other than harvesting.

In countries with extensive forest amelioration activities one of the most important problems is to include the environmental aspects in practical measures more than before.

A careful planning and development of forest amelioration techniques still require a lot of effort. Instructions should be based on research in which the benefits of forest amelioration measures in wood production are compared to possible environmental damages.

As forest drainage areas grow old both water and nutritional problems appear and the need for silvicultural cuttings increases.

Therefore the state of old drainage areas should be continuously surveyed in order to prevent the decline in tree growth. It is particularly important to follow the development of nutrient conditions of sites in peatland forests, because there are often very little nutrients as compared to the consumption of trees. Computer programmes should be developed for the estimation of the need for measures and their mutual timing.

In some countries the transition from experimental activities to large-scale practical work mainly depends on when the forest resources are used so effectively that a need will arise to increase productive forest land and the growth of the existing stands by means of drainage and fertilization. The need may arise regionally if wood must be transported from a longer distance to an industrial establishment and, on the other hand, wetlands suitable for forest drainage are found near by.

The transfer from research to practice could be helped by establishing fairly large experimental areas where the suitability of different forest improvement measures to local conditions could be tested in practice. This is what has happened in countries with long traditions in forest drainage.

Both basic and applied research are needed in order to promote the use of wetland forests in the tropics. Several countries could collaborate and funds directed to the development cooperation should be used for this purpose. Perhaps also the IUFRO Working Party dedicated to peatland affairs (S1.05-01 "Peatland Forestry") could contribute to this matter by conveying information.

A c k n o w l e d g e m e n t s

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INTENSIFICATION DE LA PRODUCTION DE GRAINES AMELIOREES DANS LES VERGERS A GRAINES FRANCAIS

Gwenaël Philippe et Daniel Terrasson

Ingénieur de recherche et chef de division
CEMAGREF
Domaine des Barres
Nogent sur Vernisson, France

FDC: 232.311.1: (44)

RESUME

L'entrée en production des vergers à graines établis par l'Etat français, conduit à expérimenter différentes techniques propres à intensifier la production.

Chez Pinus Pinaster, l'apport de sulfate d'ammoniaque a entraîné un accroissement de 50 % du nombre de fleurs femelles et a eu une action positive sur la production de pollen. De même, des fertilisations N P K ont permis d'intensifier la floraison mâle ainsi que la fructification de Pseudotsuga menziesii, la production de cônes des plants traités étant en moyenne supérieure de 70 % à celle des témoins.

Les traitements hormonaux, testés sur Pseudotsuga menziesii et Picea abies se sont également révélés extrêmement bénéfiques. Ils ont toutefois engendré une réponse insuffisante pour justifier leur utilisation à grande échelle. Des essais destinés à améliorer leur efficacité sont en cours actuelle ment.

D'autre part, les difficultés rencontrées dans le domaine de l'hybridation de Larix decidua et Larix leptolepis ont amené le CEMAGREF à imaginer une technique originale de récolte mécanisée du pollen. Le principe retenu n'altère pas la qualité du pollen, les plus anciennes récoltes ayant gardé une viabilité satisfaisante après 19 mois de conservation. En matière de pollinisation, un prototype, qui s'inspire des techniques modernes de revêtement par poudrage électrostatique, est en cours de mise au point.

INTRODUCTION

l'Etat français a manifesté sa volonté de participer activement à l'amélioration de la qualité du matériel végétal utilisé en reboisement en initiant en 1969 un programme ambitieux de vergers à graines. Il en assure le financement et la gestion est confiée au CEMAGREF (Centre National du Machinis-

me Agricole du Génie Rural des Eaux et des Forêts) qui est assisté dans cette tâche par l'INRA (Institut National de la Recherche Agronomique) pour la sélection et la multiplication du matériel de base et par l'ONF (Office National des Forêts) pour les travaux. Enfin, plus récemment, deux sociétés privées (VILMORIN, VERSEPUY) collaborent à la réalisation de cette entreprise en rémunérant l'ingénieur plus spécifiquement chargé des problèmes de fructification.

Parmi les espèces impliquées dans ce programme, figurent les principales essences résineuses de reboisement françaises (Pseudotsuga menziesii, Picea abies, Pinus pinaster, Pinus nigra var corsicana, Pinus sylvestris) auxquelles s'ajoute un petit nombre d'espèces dont la faible utilisation résulte de la pénurie du marché en graines de bonne qualité (Larix decidua, Larix eurolepis, Pinus nigra var. calabrica).

Les vergers à graines ont été dimensionnés de manière à couvrir à terme la moitié des besoins français en graine de résineux. Au total, depuis 1974, 310 ha de vergers de clones et de familles ont été installés dans 3 sites localisés dans le Sud Ouest de la France, région où les conditions climatiques sont réputées favorables à la fructification. Les plantations se poursuivent encore aujourd'hui, à un rythme toutefois moins soutenu.

Il convient de signaler que deux vergers parmi les plus anciens sont le fruit d'une collaboration franco-danoise et que, parallèlement à ce programme public, l'Etat a également participé financièrement à la création et à la gestion de 300 ha de vergers de Pinus Pinaster appartenant pour partie à des organismes privés.

Compte tenu des efforts financiers consentis, il est primordial que les vergers remplissent totalement et rapidement leur fonction de production. Il convient pour cela :

- que les floraisons soient abondantes et interviennent le plus tôt possible dans la vie des vergers,

- que le nombre de graines viables par fleur éclose soit optimal, ce qui implique une pollinisation efficace et le contrôle des populations d'insectes ravageurs des cônes et des graines.

OPTIMISATION DE LA PRODUCTION DE GRAINES

Stimulation de la Floraison

Les stratégies mises en oeuvre varient selon les essences en fonction du coût et de la rareté de la graine sur le marché français, de la surface de vergers attribuée à chaque espèce ou provenance et également de leur aptitude à fructifier naturellement.

Cas des pins (Pinus pinaster, Pinus nigra)

L'effort qui leur est consenti en matière d'induction florale demeure limité puisque, d'une part, leurs fructifications sont relativement abondantes et régulières et que, d'autre part, les surfaces dévolues à ces essences sont importantes compte tenu des besoins français.

Ces raisons ont milité en faveur de traitements simples et peu coûteux, fertilisation et cernage racinaire principalement.

Contrairement à P. nigra qui a répondu favorablement à une fertilisation NPK couplée à un cernage lorsque ces interventions avaient lieu au début de l'été, P. pinaster s'est révélé insensible à ce type de traitement réalisé durant la période présumée d'initiation florale (plusieurs dates d'application testées, de Juin à Octobre).

En revanche, des gains de production très nets ont été enregistrés dans deux vergers à la suite d'épandages d'azote (150 kg/ha) intervenus début Avril. L'apport en surface de sulfate d'ammoniaque a entraîné notamment un accroissement significatif du pourcentage d'arbres florifères et de la floraison de ces derniers, ce qui s'est traduit en définitive par une augmentation de 50 % du nombre de fleurs femelles (tableau 1). Cet engrais a également eu une action positive sur la floraison mâle, essentiellement par le biais d'un accroissement du pourcentage d'arbres très florifères.

Un traitement herbicide au glyphosate complété par des apports de phosphore (les analyses de sol indiquant une carence en cet élément) n'ont pas permis d'amélioration significative.

Il est en outre intéressant de remarquer que le sulfate d'ammoniaque procure de bien meilleurs résultats que l'ammonitrate. L'interprétation doit être recherchée au niveau de la composition de ces engrais : forme d'azote incorporée, présence ou non d'éléments secondaires tels que le soufre.

Cas de Pseudotsuga menziesii et Picea abies

Ce sont les deux principales espèces de reboisement en France. Elles s'opposent aux Pins en raison de l'irrégularité de leur fructification, du coût élevé de leur graine et du déficit du marché en semences de bonne qualité, adaptées aux conditions françaises de reboisement.

Le problème se pose avec plus d'acuité dans le cas de Pseudotsuga menziesii en raison de la faible surface de peuplements autochtones récoltables. Compte tenu du caractère aléatoire de leur fructification, la production est insuffisante pour subvenir aux besoins nationaux de sorte que les reboiseurs demeurent largement tributaires des importations de l'étranger.

Pour ce qui concerne Picea abies, l'apparition rapide sur le marché de matériel amélioré et adapté aux conditions de plaine (provenances non autochtones) est vivement souhaitée par les professionnels du reboisement.

Pour toutes ces raisons, des efforts importants ont été et seront déployés afin que les vergers à graines de ces essences jouent à plein et le

TABLEAU 1 - Influence de fertilisations azotées sur les floraisons mâle et femelle de Pinus pinaster

Traitement	Floraison femelle			Floraison mâle	
	Nbre fleurs		% arbres florifères	abondance /arbre (1)	% arbres très florifères
	/arbre	/arbre flo.			
1 - Témoin	7,9 (a)	11,2 (ab)	67 (a)	(a)	27 (a)
2 - Herbicide	9,8 (ab)	12,7 (bc)	74 (ab)	(b)	37 (b)
3 - Ammonitrate	8,4 (a)	10,7 (a)	74 (ab)	(b)	39 (b)
4 - Sulfate amm.	11,8 (bc)	14,9 (d)	77 (bc)	(d)	51 (c)
5 - 4 + 2	12,4 (c)	14,3 (cd)	83 (c)	(bc)	41 (bc)
6 - 4 + 2	13,3 (c)	15,5 (d)	83 (c)	(cd)	48 (c)

(1) classement basé sur les rangs moyens du test de KRUSKAL - WALLIS (a < b < c < d)

. les valeurs suivies de la même lettre ne diffèrent pas de manière significative au seuil de 5 %.

TABLEAU 2 - Effet de la fertilisation et du cernage racinaire sur la fructification et la floraison mâle de P. menziesii

Traitement	Fructification			Floraison mâle		
	% arbres fructifères	Nbre cônes		% arbres florifères	Abondance (1)	
		/arbre	/arbre fruct		/arbre	/arbre florif.
1 - Témoin	55,0 (a)	100 (a)	182 (a)	57,5 (a)	(a)	(ab)
2 - Nitrate 150 N/ha	76,1 (b)	170 (b)	224 (a)	73,4 (b)	(b)	(b)
3 - Nitrate 250 N/ha	75,7 (b)	181 (b)	238 (a)	72,9 (b)	(b)	(b)
4 - Ammonitrate 250 N/ha	74,3 (b)	176 (b)	236 (a)	76,0 (b)	(b)	(b)
5 - Cernage racinaire	60,2 (a)	104 (a)	173 (a)	66,4 (ab)	(a)	(a)
6 - 2 + 5	76,8 (b)	159 (b)	207 (a)	74,8 (b)	(b)	(ab)

(1) classement basé sur les rangs moyens du test de KRUSKAL - WALLIS

plus rapidement possible leur rôle de production.

La première génération d'essais faisait largement appel à la fertilisation, les engrais étant epandus en localisation, à faible profondeur, afin de limiter au maximum leur assimilation par la couverture herbacée. Une telle fertilisation s'accompagnait donc d'un léger cernage racinaire.

Puis la mise au point en Ecosse d'une technique efficace d'injection de régulateurs de croissance (PHILIPSON 1985) a permis d'envisager l'utilisation à grande échelle de ce type d'intervention. En conséquence, des essais impliquant des traitements hormonaux parfois associés à des annélations d'écorce, ont vu le jour dans un deuxième temps en vergers à graines de P. menziesii et P. abies.

Pseudotsuga menziesii

. Si les fertilisations n'ont pas été en mesure d'induire la floraison dans un verger de boutures de 6 ans jusque là non productif, en revanche elles ont prouvé leur efficacité sur des arbres greffés, de 2 ans plus âgés. Le cycle reproducteur et les périodes optimales d'intervention étant bien connus grâce aux nombreux travaux développés sur cette espèce outre atlantique (EBELL 1972 ;OWENS 1973 ; ROSS, WEBBER, PHARIS, OWENS 1985), il convenait de tester l'influence d'un cernage racinaire et de divers traitements fertilisants, dans nos conditions de production.

Les fertilisations N P K, réalisées lors du débourrement végétatif, ont permis d'intensifier la fructification et la floraison mâle, la production de cônes des arbres traités étant en moyenne supérieure de 70 % à celle des témoins (Tableau 2). Ce gain est d'autant plus satisfaisant qu'il ne s'accompagne pas d'une réduction du nombre de graines pleines ni de leur faculté germinative. Toutefois, si ces traitements ont conduit à une augmentation du pourcentage d'arbres porteurs de cônes et de fleurs mâles, ils n'ont pas été en mesure d'accroître de façon significative les quantités de pollen et de cônes produits par ces derniers.

Par ailleurs, et contrairement à ce qu'indique la littérature, l'efficacité des engrais s'est avérée indépendante de la forme sous laquelle l'azote a été apporté (nitrique pour le nitrate de chaux, ammoniacale + nitrique pour l'ammonitrate) et de la dose appliquée (150 ou 250 unités d'azote/ha). Ceci est probablement lié au mode d'épandage utilisé qui n'autorise pas une bonne répartition spatiale des engrais, de telle sorte que les parties des systèmes racinaires touchées par la fertilisation ont reçu, quel que soit le traitement considéré, une dose massive d'azote nitrique, seule forme réputée active, dépassant sans doute leur capacité d'assimilation et entraînant par là même des réponses identiques.

Le cernage racinaire, effectué 3 semaines avant le débourrement, n'a eu quant à lui aucune incidence sur la formation d'organes reproducteurs mâles ou femelles. Il n'améliore pas non plus l'efficacité de la fertilisation lorsque ces deux traitements sont couplés.

Enfin, l'effet des engrais ne s'est manifesté qu'une année, la floraison s'étant révélée extrêmement faible la saison suivante, aussi bien dans

les placettes fertilisées que témoins.

Les traitements hormonaux n'ayant été testés que récemment, nous manquons de recul pour juger de leur intérêt au champ. Des injections de gibberellines (GA 4/7) ont certes permis un accroissement spectaculaire du nombre de fleurs mâles et femelles dans un jeune verger encore non productif puisque, parmi les 50 arbres injectés, 25 se sont révélés être florifères, produisant un total de 760 fleurs tandis qu'une seule fleur femelle a été recensée sur l'ensemble des 50 témoins. La production de graines était cependant trop faible pour que cette technique soit rentable d'un point de vue économique.

Un second essai installé dans un verger à maturité devrait nous renseigner au printemps 1990 sur l'intérêt des gibberellines, de l'annélation d'écorce et d'une combinaison de ces deux traitements en tant qu'agents d'induction florale, et ceci d'autant plus que la floraison s'annonce particulièrement abondante.

<u>Picea abies</u>

Les premiers traitements testés, fertilisation et cernage racinaire, s'étant révélés impuissants à stimuler la floraison, des essais ont été mis en place plus récemment dans un verger d'arbres greffés de 12 ans afin d'évaluer l'efficacité des gibberellines (GA 4/7) et de définir leurs conditions d'utilisation.

Les premiers résultats fournissent d'ores et déjà quelques éléments de réponse et quelques pistes à prospecter (cf. tableau 3) :

TABLEAU 3 - Efficacité comparée d'injections et de pulvérisations de GA 4/7 sur <u>Picea abies</u>

Traitement	Arbres ayant déjà fructifié		Arbre n'ayant jamais fructifié	
	% arbres florifères: mâle	femelle	% arbres florifères : mâle	femelle
Témoin	3 (c)	3 (b)	2 (a)	0 (a)
GA 30 %	44 (a)	18 (a)	50 (b)	17 (b)
GA 90 %	15 (bc)	9 (ab)		
GA 30 + 90 %	47 (a)	18 (a)		
Pulvérisations				

- Les pulvérisation de GA 4/7 ne paraissent pas en mesure d'initier la floraison femelle alors que leur influence sur la production de pollen est indiscutable. En outre, pour un effet similaire sur la floraison mâle, les plants pulvérisés ont reçu au total 5 fois plus de matière active que les plants injectés. Il est donc peu probable que ce type de traitement soit économiquement rentable.

- Au contraire, les injections se sont révélées efficaces aussi bien sur des individus ayant déjà fructifié que sur des plants jusque là non florifères. Il est vrai cependant que la quantité de GA 4/7 administrée aux seconds était plus importante (25 mg par metre de hauteur au lieu de 15 mg).

- La réponse aux hormones est nettement plus forte lorsque l'injection est réalisée en début plutôt qu'en fin de période d'élongation. Un essai suggère même que le maximum d'efficacité apparait lorsque l'intervention a lieu avant que les pousses végétatives de l'année n'aient atteint le tiers de leur longueur finale.

- Le fractionnement de la dose de GA 4/7 (15 mg par mètre de hauteur soit 60 mg par arbre en moyenne) en deux apports, en début et en fin d'élongation, ne présente pas d'intérêt. D'autre part, le traitement réalisé à 90 % d'élongation ne différant pas significativement du témoin et les injections à 30 % et 30 % + 90 % fournissant des résultats comparables, il est probable qu'une grande part de l'efficacité de cette dernière modalité soit due à la première injection. Ceci laisse à penser qu'une quantité 2 fois moindre de GA 4/7 serait suffisante pour produire le même effet.

Il s'avère donc que ces régulateurs de croissance ont un effet indéniable en matière d'induction de la floraison. Si l'on prend en compte la totalité du verger dans lequel ces expérimentations ont eu lieu, les arbres ayant reçu un traitement hormonal, soit moins de 10 % de l'effectif total, ont produit 87 % des fleurs femelles et représentaient respectivement 70 % et 83 % des arbres florifères mâle et femelle.

Il n'en demeure pas moins vrai que ces traitements ont engendré une réponse insuffisante pour justifier leur utilisation à grande échelle une année où les conditions climatiques ne sont pas favorables à l'initiation florale, comme cela a été précisément le cas en 1988 lors de ces essais. C'est la raison pour laquelle ils ont été répétés en 1989, en adjoignant une annélation d'écorce aux injections de GA 4/7, de nombreux auteurs mentionnant un effet synergique lorsque ces deux interventions sont couplées.

Augmentation du Rendement en Graines

Intensification de la production de pollen

Il ressort des expérimentations précédemment décrites que les traitements susceptibles d'accroître la floraison femelle ont également une action positive sur la production de pollen. C'est la raison pour laquelle peu de recherches ont été entreprises en vue d'intensifier la floraison mâle. Tout au plus se doit-on de signaler le testage en cours de techniques ayant prouvé leur efficacité à l'étranger (strangulation ou taille de branches basses) et destinées à accélérer l'apparition de strobiles mâles chez les jeunes pins. Le but recherché étant en définitive d'accroître le rendement en graines pleines et ainsi de mieux profiter des premières floraisons "femelle".

Amélioration des conditions de pollinisation

L'essentiel des activités relatives à la pollinisation ont été entreprises dans le cadre du programme d'hybridation de Larix decidua et Larix leptolepis. Compte tenu de son caractère un peu particulier, les techniques mises en oeuvre seront développées ultérieurement dans un chapitre spécialement consacré à ces deux espèces.

D'autre part, plusieurs auteurs ayant relié la chute des jeunes cônelets de pins à une pollinisation imparfaite des ovules (SARVAS 1962 ; OWENS et BLAKE 1985), des soufflages d'air comprimé, destinés à favoriser la mise en suspension du pollen dans l'air, ont été réalisés durant la période de pollinisation dans un verger de Pinus pinaster caractérisé par un fort avortement floral. S'il est possible que ces interventions accroissent le rendement en graines, elles n'ont néanmoins pas permis d'atteindre l'objectif fixé. La cause des avortements doit probablement être recherchée au niveau des insectes ravageurs de cônes.

Lutte contre les insectes des cônes et des graines

Cet aspect important est simplement signalé ici pour mémoire et ne sera pas développé dans le cadre de cet article. Les études en cours réalisées par l'INRA visent à prévoir les risques encourus par une étude de la dynamique des populations de ravageurs (ROQUES 1988) de manière à optimiser l'efficacité des méthodes de lutte.

MAITRISE DE L'HYBRIDATION DE LARIX DECIDUA ET LARIX LEPTOLEPIS

Difficultés Rencontrées

La formule hybride retenue, mise au point au Danemark, résulte du croisement entre un clone de Larix decidua utilisé comme mère et les descendants de deux clones de Larix leptolepis utilisés comme père. Cet hybride présente une supériorité marquée par rapport aux espèces parentes, notamment pour des critères de production de bois et de forme.

Malheureusement, cette combinaison ne peut être transposee telle quelle en France puisqu'on observe sous nos latitudes un décalage phénologique entre les deux espèces concernées, ce qui interdit l'hybridation par pollinisation naturelle.

Cette contrainte nous a conduit à installer deux entités géographiquement distinctes : un verger de Larix leptolepis qui fournit le pollen et un verger de Larix decidua destiné à la production de graines hybrides, après pollinisation artificielle.

Ce choix implique donc la séparation dans le temps et dans l'espace des opérations suivantes : récolte du pollen, conservation de celui-ci après conditionnement adéquat, pollinisation artificielle.

R é c o l t e   d u   P o l l e n

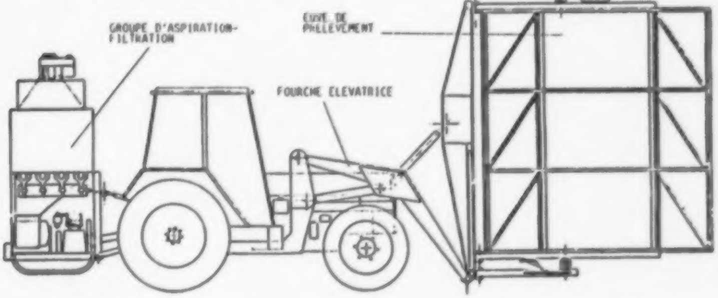
Les besoins en pollen évalués à plusieurs kilogrammes pour une production commerciale, la grande dispersion des strobiles tout au long des rameaux chez Larix et le souci de ne pas tailler trop sévèrement le verger "mâle" sont les éléments qui ont milité en faveur d'une récolte de pollen et non de rameaux florifères. En outre, le genre Larix ne produisant que de faibles quantités de pollen (100 fleurs mâles fournissent 0,3 cc, soit 500 fois moins que *Pinus sylvestris*) et les conditions atmosphériques s'avérant souvent défavorables durant la période de pollinisation, il importait que la récolte puisse se dérouler de la façon la plus complète et la plus rapide possible. Aussi le CEMAGREF a-t-il pris le parti de mécaniser cette intervention.

L'appareil retenu (cf. figure 1), adaptable sur un tracteur agricole traditionnel, comporte deux parties principales (STEINMETZ, BALDET 1987). A l'avant du porteur, se trouve une cuve destinée à enserrer l'arbre à récolter et à le confiner dans un espace clos. A l'arrière, sont réunis les dispositifs d'aspiration et de filtration ainsi que les organes de commande et de production d'énergie.

Une fois la cuve refermée sur l'arbre, celui-ci est fouetté simultanément par des flagelles et des décharges brusques d'air comprimé, provoquant la libération du pollen hors des fleurs mâles. Survient alors la deuxième phase de la récolte qui consiste à le récupérer par aspiration et filtration. Le contenu de la cuve est aspiré et acheminé jusqu'à un filtre constitué d'un tissu nylon a mailles très fines, conçu de sorte que la vitesse de l'air au moment de la filtration soit suffisamment réduite pour ne pas altérer la viabilité du pollen qu'il véhicule.

Les premiers essais ont eu lieu en 1987 et, depuis cette date, deux campagnes de récolte ont pu être réalisées, procurant respectivement 90 g et 600 g de pollen frais pour 70 et 120 arbres récoltés. Bien que le nombre d'aspirations par plant soit très variable en fonction des conditions climatiques, on peut considérer que chaque arbre est récolté 4 à 5 fois en moyenne, chaque passage durant environ 1,5 minutes.

FIG. 1 MACHINE A RECOLTER LE POLLEN



Gestion du Pollen

Après élimination des déchets par tamisage, le pollen est séché puis réfrigéré ou congelé. La teneur en eau (TE) et la température varient selon la durée de conservation : 10 % TE et + 5° C pour une utilisation dans les quelques semaines qui suivent la récolte ou 5 % TE et - 18° C pour une conservation de plusieurs mois (WEBBER 1987).

Dès la récolte et périodiquement pendant la période de stockage, la qualité du pollen est estimée par l'intermédiaire de tests de germination et de conductivité. Les premiers impliquant une certaine subjectivité de la part du manipulateur, ils ne sont plus guère utilisés. Les seconds mesurent l'évolution au cours du temps de la conductivité d'une suspension de pollen et renseignent donc sur l'intégrité de la membrane pollinique.

Il ressort de ces tests que les lots les plus anciens présentent toujours une viabilité satisfaisante 19 mois après la récolte. Néanmoins des essais ont été entrepris à l'INRA pour préciser les conditions optimales de conservation. Ils concernent notamment le conditionnement du pollen : nature, volume et degré de remplissage des conteneurs.

Pollinisation

Le recul nous manque dans ce domaine puisqu'une seule campagne a pu être effectuée jusqu'à présent. La pollinisation était réalisée manuellement, à 3 reprises pour chaque plant, à l'aide d'un pistolet pneumatique, le pollen étant dilué dans un volume égal de talc. Il s'avère cependant que cette technique est peu économe en pollen, chaque fleur femelle en ayant consommé au total 0,06 g. De plus, l'adjonction de talc au pollen semble peu satisfaisante dans la mesure où il se produit une ségrégation des deux éléments , probablement en raison d'une différence de granulométrie. Enfin, la période de floraison est souvent ventée,ce qui complique le soufflage et occasionne un gaspillage important.

Afin de limiter ces pertes, un nouveau prototype a été construit, sur le même principe que l'appareil à récolter mais fonctionnant en sens inverse. Le pollen est libéré au sommet d'une cuve renfermant l'arbre à polliniser et éliminant par là même tout courant d'air. La cible finale, c'est à dire l'ensemble des fleurs femelles, ne représentant qu'une faible part de la surface du houppier, un procédé original a été imaginé pour favoriser la rencontre du pollen et des fleurs. Il s'inspire des techniques modernes de revêtement qui font appel à l'électricité statique. L'instauration d'une tension très élevée (de 60 à 100 kVolts) entre l'objet à revêtir et l'appareil de distribution du produit engendre un champ magnétique auquel s'ajoute le chargement en électricité statique du produit projeté. Il en résulte une forte attraction, les pertes étant inférieures à 1 % dans le domaine industriel.

Les premiers essais sont satisfaisants puisqu'ils indiquent :

- que le pollen subissant une telle électrisation conserve sa viabilité tant que la tension ne dépasse pas 80 kVolts
- que, comparée à une tension de 15 kVolts, une différence de potentiel de 80 kVolts permet un meilleur "accrochage" du pollen sur l'arbre et se redé-

pose en moins grande quantité sur le fond de la cuve.

Les résultats actuels, bien qu'encore très partiels, semblent donc confirmer l'intérêt du dispositif électrostatique. Il conviendra, à l'avenir, de déterminer la tension optimale pour que les différences de conductivité mesurées entre les rameaux et les fleurs puissent s'exprimer et se traduire par une sélectivité de ces dernieres vis à vis des pousses. Des expérimentations complémentaires sont egalement requises pour préciser la quantité de pollen à délivrer à chaque arbre et le nombre de pollinisations nécessaires. Enfin, cette méthode devra être comparée à la technique manuelle en termes d'efficacité et de coût.

CONCLUSION

Les vergers à graines de l'Etat français installés depuis 1973 entrent progressivement en production. Dans une première phase, nous avons cherché, d'une part, à déterminer l'efficacité et les conditions d'application à l'échelle d'une production commerciale de divers traitements d'induction florale cités dans la littérature mais très généralement expérimentés sur des effectifs limités placés en milieu contrôlé et, d'autre part, à réussir l'hybridation en masse de Larix decidua et Larix leptolepis. Les quatre principales essences de reboisement ont réagi favorablement à au moins une des modalites testées, et une première campagne d'hybridation du mélèze a pu être réalisée au printemps 1989 après récolte mécanisée du pollen.

Pour importants qu'ils soient, ces acquis ne répondent encore que partiellement aux questions que se pose le gestionnaire des vergers à graines cherchant à optimiser la production en fonction de la rentabilité économique des traitements et de l'évolution de la demande exprimée en termes de quantité et de qualité. Les étapes qu'il reste à franchir sont encore nombreuses et concernent notamment :

- la variabilité de l'efficacité des traitements et de leur rentabilité économique en fonction des conditions annuelles plus ou moins favorables à l'initiation florale,

- l'effet de l'importance des récoltes précédentes, et donc l'optimisation de la périodicité d'application des traitements fructifères,

- les répercussions à moyen terme de la succession des interventions sur la conservation de l'appareil de production (état physiologique des vergers à graines),

- la connaissance des aptitudes familiales ou clonales, permettant d'orienter préférentiellement les traitements vers un sous ensemble d'individus,

- l'impact sur l'économie générale de la production, de techniques culturales propres à réduire les coûts de récolte (étêtage, tailles).

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APPRAISAL OF SEEDLING QUALITY TESTS

Pasi Puttonen

Senior Research Scientist
Department of Silviculture

University of Helsinki
Helsinki, Finland

FDC: 232.411--014

SUMMARY

This paper discusses the concepts applied to the characterization of seedling quality, requirements and effectiveness of such tests, and gains of the seedling quality research for regeneration research and reforestation practice. Since the recognition of the importance of seedling quality, numerous seedling quality concepts and tests have been developed, tested, and applied, but no consensus exits on quality concepts. The purpose, method, and interpretation of seedling quality tests have to be clearly specified, and the tests have to fulfill several conceptual and practical requirements. Most of all the plant physiological research, the advent of pressure chamber technique has changed the quality thinking. The most applicable methods (morphological attributes, root growth potential, and frost resistance) describe the seedling condition and predict planting performance only in specific situations where the sources of variation are known. Emphasis on quality has resulted in detailed characterization of the whole nursery growing environment, suggestions of major areas for improvement, and it has increased the cooperation with nurserymen, field foresters, nursery and reforestation scientists.

Keywords: acclimatization, performance potential, prediction ability, whole-tree physiology.

INTRODUCTION

Characterization of planting material is regarded essential for the success of reforestation efforts. The workshop "Techniques for Evaluating Planting Stock Quality" in 1979 (Planting... 1980) initiated the current discussion of seedling quality, and the workshop "Production of Bareroot Seedlings" in 1982 (Duryea and Landis 1984) and "Evaluating Seedling Quality" in 1984 (Duryea 1985) gave further encouragement for seedling testing. But what are the characteristics of seedlings which determine seedling performance in the field and thus enable a full expression of site

and plant growth potential ? This paper considers the concepts applied to the characterization of seedling quality, requirements and effectiveness of such tests, and gains of seedling quality research for reforestation research and practice.

CONCEPTS OF SEEDLING QUALITY

Myriad of Quality Concepts

A non-quantitative statement of seedling characteristics important to field survival and growth can be derived from general principles and requirements for seedling establishment (Burdett 1983). For example, the Finnish legislation on forest regeneration material states that the seedlings should be healthy and vigorous as well as otherwise appropriate (Decision... 1979). In 1979 the definition of seedling quality was expressed as the degree to which a seedling realized the objectives of management, "fitness for purpose" (Planting... 1980). Thereafter, the seedling quality terms have been elaborated from "seedling vitality", "seedling vigor", through "performance and material attributes", and "planting performance potential" to working definitions of "physiological quality". Seedling quality has, however, turned out to be difficult to describe in terms of measurable characteristics of the planting material. There seems to be no consensus on quality concepts among researchers and nurserymen.

The actual performance of planting material depends particularly on the environmental conditions to which the seedling will be exposed following outplanting which vary from site to site and within sites. Therefore, it is incorrect to use the term quality in predictions because survival and growth of seedlings, quality, can be determined only after a period of time in the field, and after being rated against the objectives of management. Seedling characteristics assessed to predict survival and growth express only performance potential of the planting stock (Sutton 1982). Here "quality" is used as a general term and when a reference is made to predictions of planting success the term "seedling performance potential" is used.

Development of Quality Concepts

The concept of acclimatization describes establishment of seedlings in the field in terms of modifications in plant physiological processes which result in adaptative changes in seedling anatomy and morphology. Seedling performance potential should be determined on the basis of processes and characteristics which are vital to acclimatization at the planting site. It is further evident that a performance potential attribute must correspond well with field performance, i.e. it must have a good predictive ability.

The performance potential characteristics should be derived

from the growing conditions, including both microsite and macroclimate of planted seedlings, and then tested in the field over a number of years. The performance potential characteristics cannot be based solely on the properties of a year's seedling materials. First, because of year-to-year variation exists in planting material, especially in bareroot planting material (Jalkanen et al. 1988), and second, because of annual variation in planting environment.

CRITERIA FOR QUALITY TESTS

Purpose of Testing

Purposes of testing vary in the phases of growing, pre-lifting, and pre-planting. Objectives of using morphological attributes in assessing seedling performance potential in the phases of growing are mainly to meet set physical attribute standards for height, root collar, and root development. Objectives of using physiological attributes can be to ensure undisturbed growth, characterize nutrient status, detect injuries, control dormancy status, find lifting windows, permit field overwintering, and enable storability. At the phase of pre-lifting, the objective is to predict storability, but most importantly planting performance. The purpose of pre-planting tests is to predict planting success, survival and growth.

Criteria for methods of testing

Zaerr (1985) suggested that an ideal test of plant vigor should be: (1) rapid, yielding final results immediately, (2) simple to understand and use at all levels of operation, (3) inexpensive, accessible to all potential users, (4) reliable, (5) non- destructive, enabling tested plants to be outplanted, (6) quantitative and non-subjective, allowing probability values to be assigned to results, and (7) diagnostic, so that the cause of seedling damage could be indicated. Puttonen (1989) defined further intentional criteria of seedling performance potential tests from the viewpoint of acclimatization process in the field.

1. Basis of assessment - The basis for the measurement of performance potential (empirical or mechanistic) affects the generality of results. Whereas mechanistic models should be better at prediction than empirically fitted curves, the empirical models are frequently of great utility (e.g. Sokal and Rohlf 1981). However, empirically fitted curves represent the best fit to a set of data and the constants of the function may not possess any inherent meaning. Strictly, the results of a factorial experiment are applicable only to similar conditions if the experimentation does not include a general theory into which the results could be fitted (Hari et al. 1983).

2. Ability to accommodate changes in seedling - As suggested

by Sutton (1979), a seedling performance potential test should take into account any substantive changes in the interim from the nursery to the planting site, e.g. in water or dormancy status. Time of lifting and length of cold storage may influence the ability of a test to predict potential field performance, e.g. because of a change in the status of dormancy, cold hardiness, or plant water status. Therefore, the seedling performance potential test should be done close to the time of outplanting to have an adequate predictive value.

3. Prediction span - The predictive ability of a test depends on when it is used; during the growing phase, before lifting, or before planting, and what is being predicted; seedling survival, shoot length growth, or dry matter production. Since performance potential tests evaluate seedlings stress resistance, attention should be paid to the possibly different sensitivity of performance potential parameters. Seedling survival and descriptive evaluation of vigor were relatively insensitive response indicators whereas terminal growth reduction and weight gain reduction were sensitive to the stresses imposed (Ritchie 1986).

4. Rules and scale of measurement - Any test should give results in units which allow the application of appropriate statistical analyses relating the test result to field performance (see 5. below). Interval and ratio scale of measurement increases availability of statistical methods necessary for valid predictions (Sokal and Rohlf 1981). The use of indices as performance potential attributes (e.g. morphological indices by Iyer and Wilde 1982) is problematic. First, the indices may result in meaningless units in terms of describing the acclimation process. Second, use of indices implies strongly that a single parameter (in single-tree grading) or statistic (in batch grading) could be used to describe establishment potential of a plant population. A single index parameter or statistic is difficult to interpret and may not summarize the acclimatization potential of seedlings. Indices as attributes of seedling performance potential are hard to avoid - root growth capacity and current measures of dormancy are also indices.

5. Statistical quality control - For testing of seedling performance potential, the sampling procedure must allow a valid inference about the stock sampled with a required degree of accuracy, precision, and repeatability for management decisions, i.e. serve as a method for statistical quality control. The proportion of the variation in a seedling performance variable (dependent) explained by a performance potential attribute (independent) can be required to be large for decision purposes. Also, the confidence limits of a performance potential attribute for characteristics of field success should be narrow. However, in practical performance potential tests the proportion of unexplained variation in growth variables is large (e.g. for the stress resistance test Lavender et al. 1978; for RGP, Sutton 1983, Binder et al. 1989).

Sampling size affects the amount of variability detected in a seedling population. Sampling size is largely determined by the need to quantify the accuracy of the performance potential

estimate. For a seedling lot of known variance, sample size of 0.1 % of the lot size can be effective (Puttonen, unpublished data), but the size may not be representative for common lots (Landis and Skakel 1989).

The statistical control assumes also that the independent variable is relatively easy to record and that it can be measured without an error (Sokal and Rohlf 1981). This might not be true for seedling's physiological attributes which vary because of seedling size, genetic factors, microsite differences in the nursery and random error, which results in high within-test variation. Measurement of dependent variables (growth and survival) are subjected to the same sources of variation in the field. The proportion of explained variation and correlation coefficient are statistics of the very experiment reported, and therefore, the results must be generalised with caution. To increase the applicability of the results, also the confidence intervals should be reported, preferably graphically, for the relation between variables of seedling performance potential and variables of field success.

6. Applicability to different methods of characterization - Results of performance potential characterization based on sample seedlings yield statistics for a population. Single seedling characterization provides information on each seedling but it is more laborious to apply. Single seedling characterization has been used in Finland from mid-1970 by culling the individual bareroot seedlings at the lifting phase either in the nursery field or in a storehouse (Räsänen and Leikola 1974) with fairly good results (Rikala 1989). The statistical and technical applicability of a method to single characterization versus sample characterization should be clearly defined.

7. Design for site specific conditions - A performance potential test is typically general rather than being designed for specific conditions. However, the site dependent nature of seedling acclimatization implies that a test method should give results which are applicable to a known set of conditions, e.g. to the most probable or severe conditions at the planting site. Site specific tests could be developed, e.g. for RGC-test (Ritchie 1984). Also, the test results must be evaluated against the objectives of the reforestation management: objectives of local fuel wood production and industrial raw wood production differ.

8. Applicability for quality control in seedling nursery - If performance potential attributes are used to regulate the growing process in the nursery (Räsänen 1980) the test must give usable control information. A repeated sampling may be necessary in controlling production in seedling nurseries. A non-destructive test (e.g. needle samples) allows repeated sampling of a seedling or a seedling lot. Repeated sampling may, however, perturb the seedling. As a corollary, a destructive test should use only a small amount of sample material. The proper sampling size is, however, determined also by other factors than amount of sampling material (see 5. Statistical quality control).

EVALUATION OF SEEDLING PERFORMANCE PREDICTORS

Difficulties in Making Predictions

Prediction of seedling performance in the field is the most important objective of seedling testing. Changes in the growing environment or in the seedling may outdo the prediction ability of a method. An incorrect prediction may arise from 1) changes in the growing environment (e.g. air and soil temperature) or changes in the studied phenomenon (e.g. plant dormancy status), 2) inadequate hypothesis formulation of the phenomenon, 3) sampling errors, 4) errors in measurement, 5) errors in the generalization of the results, and 6) from assumptions made in the hypothesis formulation or experimentation.

Since seedlings are typically more acclimatized to the nursery conditions than to planting site conditions, assessment of physiological performance potential attributes includes a systematic error. Sampling intensity is always a compromise between cost and accuracy. Pure measurement errors are due to technical limitations. But errors can arise also from measuring imprecisely because of wrong assumptions or inadequate problem formulation. Failures in the generalization of results is an analytical problem. Therefore, all the precautions given by adequate and proper statistical analyses should be used (Warren 1986). Assumptions are simplifications of the problem because of cost limitations, or as in many cases, due to inadequate knowledge.

Morphological Attributes

The major advantage of morphological characterization is the simplicity of application on a large scale. Morphological characterization is usually a non-destructive method which allows repeated sampling. Most morphological measures are quantitative, thus allowing a statistical quality control. Morphological characteristics at any particular time only express the dimensions of seedlings. The stresses to which planting stock are commonly subjected during seedling handling, can restrict the use of assigned morphological grades (Sutton 1979, Schmidt-Vogt 1980). Correlations between seedling size and postplanting success are inconsistent (Hermann and Lavender 1976, Chavasse 1977, Hobbs 1984). The results emphasize the role of microsite of growing seedlings. Further, morphological characteristics are generally not diagnostic of vigor or damage.

Nurseries aim to produce seedlings of uniform size and, implicitly, of uniform physiological condition. These goals are nowadays best achieved in containerized seedling nurseries. Grading and culling are further used to achieve uniform planting stock. However, absence of variability in morphological attributes neither describes nor guarantees performance potential. Uniform planting stock may not be appropriate for all sites if it reduces genetic variability and eliminates genotypes adapted to harsh microsites (Lang 1989). Then physiological seedling characteristics are important. According to simulations, and thus to be validated,

markedly reduced variation on plant material is unlikely to be beneficial for wood production (Cannell 1989).

Physiological attributes

Numerous methods to evaluate the physiological performance potential of seedling stock have been proposed, tested, and applied (for references see e.g. Puttonen 1989). The physiological methods are mostly empirical and correlative in nature with less emphasis on general mechanistic theory. There is nothing wrong with the empirical models if they work.

Of all the numerous physiological seedling quality tests, root growth potential (RGP) is the most widely used as a predictor of seedling performance after planting and thus describes well the difficulties in quality characterization. RGP is a measure of a seedling's potential ability to re-establish soil- root contact in test environment. However, there have been only a few reports on good relationship between RGP and postplanting performance (Ritchie 1985). Typically, field performance of seedling performance is highly site- and treatment-specific, showing low and inconsistent correlation between RGP and field root growth. RGP is influenced e.g. by provenance, genotype, variety of cultural practices, dormancy state, and test environment (Ritchie and Dunlap 1980, Sutton 1983, Burdett 1987, Binder et al. 1989).

The relationship of RGP to planting performance can be expected to be variable since RGP is mostly a correlative, empirical measure of plant performance potential. Other limitations of the RGP, and many other tests, are that they are not diagnostic, depend on the sampling time, and may not take into account changes in the interim between nursery and planting site, i.e. tests give point estimates only. The results of RGP tests are not calibrated for a specific planting site although the relationship between laboratory RGP and seedling performance in the field varies with circumstances. Test conditions could be tailored to species and sites (Ritchie 1984). Root characteristics which are known to influence planting performance have not been combined into a holistic, quantitative approach.

None of the physiological evaluation methods of planting stock quality (foliar analyses, chrolophyll content, RGC, carbohydrate analyses, photosynthesis rate, impedance) regarded possibly useful in 1979 (Planting... 1980) has proved its full applicability.

PRACTICABILITY OF SEEDLING PERFORMANCE TESTS

The question of which test is generally superior, remains still unanswered because species, nursery, and planting site conditions vary largely. In a particular test situation, the growing conditions at the planting site and managerial needs must be applied to the components of the criteria to find a test or a

set of tests, which then have to be interpreted correctly. For example, when there is a need to detect possible seedling damages the before outplanting, the quickness of the vigor assessment may outweigh cheapness and a lower prediction ability of the method.

As no single test can be applied throughout the seedling growing, a battery of test is needed in the nursery (McCreary and Duryea 1987). For predicting planting performance potential, morphological traits describes the overall suitability of a seedling for a planting site, and physiological traits could predict the acclimatization potential of the seedling at the site. Generally, attempts to achieve a high correlation between a performance potential attribute and field performance implies a far greater control over the production of seedlings in nurseries than is currently practiced (Langerud et al. 1988).

GAINS FOR REFORESTATION RESEARCH AND PRACTICE

Research

Seedling quality research has increased the cooperation with nurserymen, field foresters, nursery and reforestation scientists. Seedling quality testing has become a sort of "reforestation science", which applies a number of disciplines of natural science, enterprise management, and economy. Perhaps most of all the plant physiological research, the advent of pressure chamber technique has changed the quality thinking. The approach emphasizes importance of adequate seedling water status in the nursery and especially during the phase of transport and planting.

Great number of seedling quality related publications indicates substantial research effort. Quality test research has shown the complexity of managing living organisms, both the seedlings and human beings involved. Seedling quality assessment can be regarded as whole-tree physiology. Seedlings, as large trees and whole stands, are still however treated as single tissue systems where scaling up from leaves to seedling crops for interpretation or scaling down from leaves and root for mechanisms is needed. Among topics, which have not been addressed sufficiently, are the role of genotype in acclimatization, phenotypic plasticity of seedlings, annual cycle of trees with accompanied stress resistance, and population dynamics of planted trees.

Currently available tests of seedling performance potential compromise several of the requirements for a quality test. It is evident that many of the performance potential tests and their underlying principles need further study. Typically, the measures of physiological plant processes have a variability all too large for predictive purposes. The proportion of explained and unexplained variation in measures of field success of different performance potential attributes should be examined with more critical attention. Changes in the planting environment are probabilistic and those in seedlings are mechanistic. The first can

be described with distributions of environmental variables, and the second with physiological models. Thereafter, an interaction of performance potential attributes and planting site could be studied with Geographical Information Systems.

Reforestation Practice

Several quality workshops in 1980ies inspired nursery manages and reforestation specialists to start seedling testing programs, with own built equipments or by independent facilities. Practical gains achieved depend how well the tests methods were technically applied and the results interpreted. For example, poor sampling and storage of test seedlings can confound the test results. Seedling material produced has become more uniform as growers and users have specified standards. More uniform planting stock has improved profitability of nursery operations and perhaps reduced expenditures in the establishment phase.

Emphasis on quality has also resulted in detailed description of the whole nursery growing phase, description of principal contributors to variability, suggestions for major areas of improvement, and consequently development of integrated growing schedules and standards, nursery information systems coupled to field management of planting (Mason et al. 1989) Growing seedlings has become a biotechnical process, the progress of which can be measured and directed (Räsänen 1980). Increased physiological research, technical development of tools and machines, rationalization, and automatization enable better control of the growing process. Also the description and management of planting environment (Hobbs 1984) has gained more emphasis as a part of the reforestation process (Räsänen 1980) but more research on effects of microsite on seedlings is needed.

In the practice, however, some basic concepts of seedling quality tests have been oversimplified, or expectations from the tests have been too high. Many of the test methods are specific research tools and transfer of research technology to operational seedling evaluation has been premature. Many of the test methods lack strict economical cost-benefit analysis. Nevertheless, research findings could be applied more efficiently in seedling growing and quality control systems. In many cases a complete overhaul of the nursery production system is postponed because of short term economical perspectives.

A new cycle of quality testing has already started, now for cuttings and plantlings. The proper accomplishment of the tests depend on advances in ecophysiology and on the cooperation with everyone involved in production and use of planting material so that there is not transfer of research technology but technological transfer. Public credence on forest regeneration practices relies on factual use of reforestation science.

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DIE WALDBAULICHEN MöGLICHKEITEN UND GRENZEN VON MISCHBESTOCKUNGEN

Jean-Philippe Schütz

Professor für Waldbau
ETH-Zentrum
CH-8092 Zürich, Schweiz

FDC : 181.41: 228.3

SUMMARY

Silvicultural Possibilities and Limits of Mixed Forests

The principle of research on the diversity of species trough the establishment of forest populations with a rich and thoroughly mixed species composition is justified in multifunctional silviculture, not only by the principles of natural ecology (principle of ecological stability) but also by the necessity for adaptation to the changing needs of society.

In the natural forests of Europe, a mixture of species is rather the exception than the rule, as one or a few species usually dominate due to their greater competitive ability. That leads to a natural tendency towards a decrease in the number of species and the establishment of uniform, monospecific populations. On the other hand, an element of sociability, mainly given by shade tolerance, is present in some species, leads to differenciation and can be promoted. In order to attain the aims stated above, it is appropriate to learn and promote natural trends towards the diversity of structures and species compositions. These should be investigated in terms of the exploitation of soil space by both the main and fine root systems, crown competition, and mineralisation of litter.

Keywords: mixed forests, competition, diversity, crowns.

EINFüHRUNG

Obwohl die Mischung von Baumarten im Naturwald nicht selten vorkommt, vertritt die klassisch orientierte Forstwirtschaft und dementsprechend auch die Waldbaulehre im allgemeinen den Umgang mit Reinbestockungen oder mindestens mit flächenweise getrennten Baumartenmischungen. Bei der künstlichen Bestandesbegründung wird der rationell denkende Waldbaupraktiker kaum Einzelmischungen vorsehen, ausser für den eher speziellen Fall der Mitbegründung eines boden- und stammpfleglichen, sozial untergeordnet bleibenden Nebenbe-

standes.

Eine solche Haltung ist nicht nur das Resultat rationeller Denkschablonen, sondern ist im wesentlichen auf die angebliche Erfahrung zurückzuführen, wonach die Pflege und Behandlung von Mischbestockungen wesentlich schwieriger sei als diejenige von Reinbestockungen. Diese werden deshalb als waldbaulich kostengünstiger eingestuft. Dass grossflächig begründete Reinbestände, sog. Monokulturen, aber mit grossen Risiken behaftet sind, zeigen zahlreiche negative oder gar katastrophale Ereignisse, wie grossflächige Zusammenbrüche infolge Stabilitätsverlustes oder Krankheiten. Oekosystemisch denkende Forstleute vertreten daher die Auffassung, dass aus Gründen der Risiokoverteilung und Risikominimierung - zwei im Waldbau bedeutsame Prinzipien - generell möglichst feine, waldbaulich aber noch sinnvolle Baumartenmischungen angestrebt werden sollten. Diese Vorstellung gilt heute mehr denn je, da insbesondere zivilisatorische Einwirkungen eine Destabilisierung unserer Waldökosysteme zur Folge haben.

Andere als nur ethische oder ökologische Gründe sollten uns ebenfalls dazu bewegen, die Probleme von Mischungen besser zu studieren und zu verstehen, auch wenn dies mit wesentlich grösseren Schwierigkeiten verbunden ist. In Mischungen können wir nämlich das Ergebnis komplexer ökosystemischer Wechselwirkungen positiver und negativer Art beobachten. Die Regelung komplexer Oekosysteme kann in der Tat als ein ständiges Spannungsfeld von stabilisierenden und destabilisierenden Kräften interpretiert werden. Aus dem Verhalten der an einer Mischung beteiligten Baumarten können wir wichtige Erkenntnisse über deren Eigenschaften in diesem Spannungsfeld ableiten und zugleich die Regelmechanismen des gesamten Systems besser verstehen. Im Bestreben, sinnvolle Kompromisse zwischen Oekologie und Oekonomie zu finden, ist es nicht abwegig, sondern waldbaulich zukunftsträchtig, die günstig wirkenden Prozesse des Systems zur Geltung zu bringen bzw. zu versuchen, die Selbsregulierungs- und Selbststeuerungsmechanismen zu fördern.

DAS ERSCHEINUNGSBILD DER MISCHUNGEN IN NATURWäLDERN

Am besten kann man diese Probleme durch Beobachten von Mischungsverhältnissen und deren Entwicklung angehen. Im Naturwald kommen die Baumarten in recht unterschiedlichen Mischungsformen und -verhältnissen vor. Sie sind das Ergebnis verschiedenster Prozesse, welche es gut zu charakterisieren und zu definieren gilt, um die Wirkungsmechanismen einigermassen zu verstehen. Wir stützen uns dabei im wesentlichen auf die Erfahrungen aus der Urwaldforschung in zentraleuropäischen Wäldern. Diese Wälder sind im Gegensatz zu anderen Regionen der Welt, insbesondere zu Amerika, durch eine relativ grosse Baumartenarmut gekennzeichnet. Aus diesem Grunde vereinfacht sich auch die Interpretation der Wirkungsmechanismen. Diese geringe natürliche Baumartenvielfalt erklärt, weshalb die Reinbestockung, z. B. Buchen-, Fichten-, Eichen- und Kieferwälder, das grossräumig am meisten vorkommende Naturwaldmuster ist. Der Grund für diese Erscheinung liegt in der durch den Standort bedingten Herrschaft einer Baumart, die zur natürlichen Unterdrückung der anderen Arten und zu einer natürlichen Entmischung führt. Schon aus dieser Erkenntnis kann man eine erste wichtige Aussage ableiten, und zwar, dass es nicht sinnvoll ist, Mischungsverhältnisse erklären zu wollen, ohne dabei die

Einflüsse der Standortsfaktoren auf das Gedeihen und die Entwicklung der Baumarten zu berücksichtigen.

Aus den Mischungs- und Entmischungstendenzen lassen sich als Ergebnis zwei Eigenschaften der Baumarten erkennen: Einerseits die Herrschaftsfähigkeit und andererseits die Verträglichkeit oder Soziabilität der Art. Herrschaftsprägende Merkmale sind eine grosse erreichbare Endhöhe, eine Wuchsüberlegenheit insbesondere in der Jugend, eine Konkurrenzkraft gegenüber anderen Arten, d.h. die Fähigkeit, das Kronendach zu schliessen oder wenig Licht durchzulassen, eine gewisse Langlebigkeit sowie eine gute Verjüngungskraft. Zu den Eigenschaften der Verträglichkeit gehören primär die Schattentoleranz sowie die Widerstandskraft gegenüber biotischen Schäden und allelopathischen Einflüssen.

Je günstiger und gleichmässiger die Standortsverhältnisse für das Baumwachstum sind, desto ausgeprägter kommen die Herrschaftseigenschaften der dominierenden Art zum Ausdruck, und um so stärker ist entsprechend die Tendenz zur Entmischung, und um so wahrscheinlicher die Ausbildung von gleichförmigen und reinen Bestockungen. Die Verträglichkeitseigenschaften hingegen verleihen den Baumarten gute Beimischungsfähigkeiten.

Weist eine Baumart gleichzeitig hohe Herrschaftseigenschaften und eine gute Verträglichkeit auf, wie z. B. die Buche, kommt sie zur Alleinherrschaft. Verliert sie aus standörtlichen Gründen etwas von ihrer Herrschaftsdominanz, wird diese Baumart zur idealen Mischbaumart. Baumarten, wie Eiche oder Kiefer, die aufgrund einer schlechten Schattentoleranz eine geringe Verträglichkeit besitzen, aber grundsätzlich hohe Herrschaftseigenschaften aufweisen, bilden natürliche Reinbestockungen auf jenen Standorten, wo konkurrenzkräftigere Arten nicht mehr zu gedeihen vermögen.

Von Natur aus trifft man gemischte Bestockungen auf Standorten, wo die Wuchskraft der dominierenden Buche nachlässt, d.h. einerseits in der montanen Stufe, wo sie sich mit Tannen und auch Fichten vergesellschaftet, und andererseits in tieferen Lagen auf Standorten, welche für die Buche eine ungenügende Wasser- und Nährstoffversorgung aufweisen, und wo sie sich mit Eichen oder Kiefern vermischt. Im gleichen Gedankengang versteht es sich von selbst, dass von Natur aus kleinräumig heterogene Standorte zu einer Vielfalt in der Baumartenzusammensetzung und auch zu einem stufigen Bestandesaufbau führen.

WALDBAULICHE BEDEUTUNG DER MISCHUNGEN

Wenn im Sinne einer mehrfachen Funktionserfüllung das oberste Ziel des modernen Waldbaus darin bestehen soll, ökologisch möglichst ausgewogene und an die Veränderungen der gesellschaftlichen Bedürfnisse anpassungsfähige Bestockungen zu schaffen, sind wir sehr auf die Realisierung optimaler Mischungsformen angewiesen. Primär zu berücksichtigen ist daher sicher die Verträglichkeit der zu assoziierenden Baumarten, weil die Unterschiede in den Herrschaftseigenschaften durch die Waldpflege, d.h. durch eine Regulierung der Konkurrenz in der Bestockung mittels waldbaulicher Eingriffe, beeinflusst werden können. Allerdings muss betont werden, dass je ausgeprägter die vom Standort ausgehenden Herrschaftsunterschiede zwischen den gewählten Baumarten

sind, desto kräftiger wird man bei der Waldpflege eingreifen müssen, um der natürlichen Tendenz zur Entmischung entgegenzuwirken. Jede beliebige Mischung ist letztlich realisierbar, wenn man bereit ist, einen entsprechenden Pflegeaufwand zu betreiben. Musterbeispiele dafür sind die Arboreten. Ob dieser Aufwand sinnvoll oder gerechtfertigt ist, bleibe dahin gestellt. Umgekehrt weiss man aus der Urwaldforschung, dass die im Wuchstemperament abgestimmten Baumarten (wie Fichte/Tanne, Bergahorn/Esche) viel einfacher in feiner Mischung zu assoziieren sind, da die Selbststeuerungsfähigkeiten eines solchen Systems besser sind.

Auf einem bestimmten Standort kann man die Herrschaftstendenzen und -unterschiede der Baumarten in einer ersten, groben Annäherung durch ihr Wuchsverhalten veranschaulichen (siehe Abbildung 1). Baumarten, die sich in der Jugend langsam entwickeln und gleichzeitig unverträglich sind, d.h. wenig Schatten ertragen, wie z. B. Eiche oder Kiefer, müssen in grösseren reinen

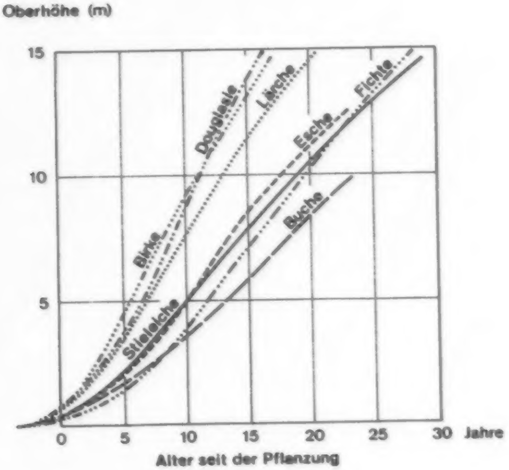

Abbildung 1: Unterschiede der Höhenwuchsleistung mehrerer Baumarten in der Jugend auf mittleren Standortsverhältnissen (Standortsverhältnisse: Waldmeister-Buchenwald).

Mischungsformen begründet oder durch Pflege in solche Formen überführt werden. Andererseits können die zur Herrschaft tendierenden, sich rasch entwickelnden Baumarten nur mit jenen Baumarten assoziiert werden, die eine hohe Verträglichkeit aufweisen, d.h. schattentolerant sind. Dabei müssen die zeitlich langfristigen Positionsveränderungen berücksichtigt werden. Die sich langsam entwickelnden, verträglichen Baumarten sind dank einem nachhaltigeren Wuchspotential oft in der Lage, eine am Anfang im Höhenwachstum überlegene, später aber rascher nachlassende Baumart einzuholen, zu überwachsen und

später sogar zu verdrängen. Es ist deshalb notwendig, die Mischungsverträglichkeit der Baumarten nicht nur aufgrund der Jugendentwicklung zu beurteilen, sondern vielmehr aufgrund einer umfassenden Kenntnis ihres gesamten ökologischen Verhaltens und ihrer Entwicklungseigenschaften.

MISCHUNGSZIELE BZW. MISCHUNGSSITUATIONEN

Die Art und Weise der Assoziierung von Baumarten hängt im wesentlichen von der Festlegung der Mischungsziele ab. Ob mit der Mischung nur ein boden- oder stammpflegerischer Effekt oder aber eine Hauptholzproduktion, allenfalls eine additive Produktion, angestrebt werden soll, hat für die Festlegung der Mischungskonzeption grosse Konsequenzen. Es ist notwendig, auch im Hinblick auf eine begriffliche Klarstellung, grundsätzlich zwischen den folgenden Mischungsmöglichkeiten zu unterscheiden (siehe Abbildung 2).

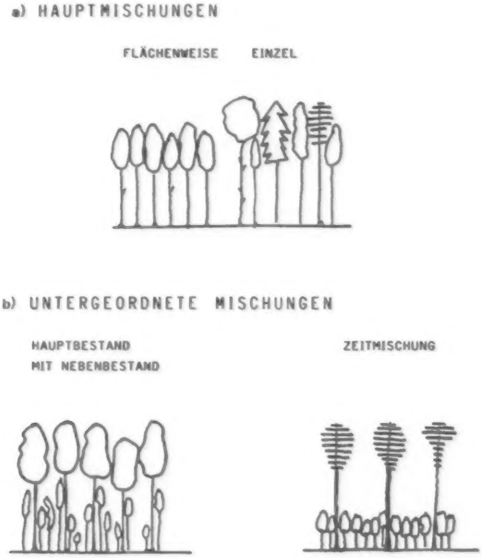

Abbildung 2: Funktionelle Hierarchie der Mischungen

Funktionell kann man zuerst die Form der <u>Hauptmischungen</u> definieren, in denen die Baumarten gleichwertig assoziiert sind, d.h. sich synchron entwickelnd in der Oberschicht behaupten und zu gleichwertigen Leistungen (z. B.

Qualitätsholz) fähig sind. Ist nur von Mischungen die Rede, ist die Form der Hauptmischung als Normalfall gemeint. Waldbaulich wichtig ist dabei die Mischungsform, d.h. die Art und Weise, wie die Baumarten räumlich auftreten, ob sie einzelweise verteilt sind oder in grösseren Aggregaten (Gruppen, Horste usw.) als sogenannte flächenweise Mischung vorkommen.

Im Gegensatz dazu können wir die Form der untergeordneten Mischungen definieren, in denen gewisse assoziierte Baumarten einer oder mehreren Hauptbaumarten sozial untergeordnet sind, d.h. nie zu direktem Lichtgenuss gelangen sollen. Die Unterordnung kann die Folge eines Altersunterschiedes sein oder aus einer absichtlichen Unterstellung bzw. Unterdrückung der notwendigerweise schattentoleranten untergeordneten Baumarten entstehen. Hier unterscheidet man einen Haupt- von einem Nebenbestand.

Eine weitere Mischung stellt die Zeitmischung dar, in welcher die Individuen zeitlich begrenzt und für eine unterschiedlich lange Zeitdauer assoziiert sind. Dies ist zum Beispiel der Fall im Ueberhaltbetrieb oder auch im Falle des Vorbaus. Nach einer mehr oder weniger lang andauernden Mischung, allerdings in unterschiedlicher Schichtstellung, ergeben sich am Ende völlig andere Baumartenzusammensetzungen.

Zuletzt wollen wir noch den besonders interessanten Fall der vertikalen Mischung hervorheben, welche vor allem im Plenterwald, aber auch im früher auf Laubholzstandorten praktizierten Mittelwaldbetrieb vorkommt. Das interessante daran ist, dass eine ständige Erneuerung der Bestockung auf kleinster Fläche stattfindet, und zwar durch Aufstieg aus den untersten Bestandesschichten bis hinauf zur Oberschicht ohne Auflösung der Hauptbestockung. Solche vertikal gegliederten Bestockungen sind im Waldbau der Inbegriff für eine Konstanz in der Funktionserfüllung, und aus diesem Grunde erhalten sie einen besonderen Stellenwert. Allerdings muss man feststellen, dass diese Formen an sich grundsätzlich labil sind, und sich nur dank regelmässiger waldbaulicher Steuerungsmassnahmen, d.h. Eingriffen, erhalten können.

DURCH DIE MISCHUNG POSITIV UND NEGATIV WIRKENDE PROZESSE

Aus der Fülle der geschilderten Mischungsmöglichkeiten, welche alle ihren waldbaulichen Sinn haben, interessieren uns vorderhand die Hauptmischungen, da darin das Gleichgewicht zwischen den beteiligten Baumarten offensichtlich am empfindlichsten ist. Es ist deshalb schwierig, dieses Gleichgewicht über einen sehr langen Zeitraum hin zu erhalten. Abgesehen von eher ethischen Ueberlegungen und generellen Interessen der Baumartenvielfalt wird man sich fragen, aufgrund welcher Abläufe oder Prozesse positive und negative Wirkungen in der Mischung entstehen.

Ebenso entscheidend wie das Durchsetzungsvermögen der Baumarten aufgrund ihres Höhenwachstums oder ihrer Kronenausdehnung ist die Entwicklung im Bereich des Wurzelsystems. In der Tat erscheint die Erschliessung des für die Bäume eng begrenzten und knapp zur Verfügung stehenden Mediums Boden entscheidend. Es geht dabei nicht nur um die Bewurzelungstiefe, sondern auch um die für die Ernährung und Baumstabilität wichtige Feinwurzeldichte.

Aus entsprechenden Beobachtungen von Meusel (1951) in naturnahen Eichen-Linden-Mischwäldern in mittleren ostdeutschen Trockenregionen geht hervor, dass die Kohabitation unterschiedlich tief bewurzelter Baumarten zu einer besseren Bodenerschliessung führen kann (siehe Abbildung 3). Die tiefwurzelnden Eichen ertragen die Nachbarschaft der oberflächlich wurzelnden Linden und Hainbuchen offensichtlich besser. Weitere ähnliche Beobachtungen ergaben, dass zum Beispiel in der Mischung Fichte-Buche die sonst relativ oberflächlich wurzelnde Buche ihr Wurzelwerk tiefer anlegt. In der Mischung Fichte-Buche erreicht die Fichte deswegen, neben anderen Gründen, grössere Endhöhen (Mettin 1985; Eckhart et al. 1961) und um 15 % bessere Volumenleistungen (Flury 1926, 1930; Burger 1941; Magin 1954; Kennel 1965) als in Reinbestockung, da die Wurzelkonkurrenz im Mischwald geringer ist. Bei der Buche ist es allerdings gerade umgekehrt als bei der Fichte. Die Leistung der Buche ist in Beimischung niedriger als in Reinbestockungen (Kennel 1965; Otto 1986). Des weiteren ist nicht nur die Bewurzelungstiefe massgebend, sondern

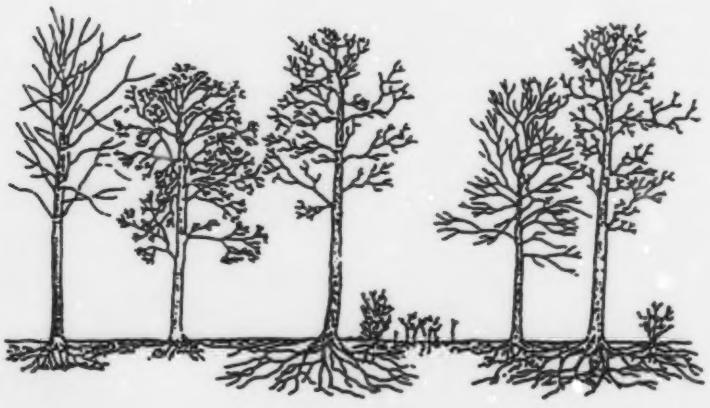

Abbildung 3: Die unterschiedliche Bewurzelungstiefe der Baumarten in einem Mischwald erlaubt eine günstige Wurzelraumausnützung. Beispiel natürlich trockener Eichen-Linden-Mischwälder (nach Meusel, 1951).

auch die Erschliessungsdichte des Feinwurzelsystems, welches für die Auflockerung bzw. die Humusbildung im Boden und demnach für die Ernährung entscheidend ist (Santantonio et al. 1977; Fogel 1983; Nadelhoffer et al. 1985). Dabei spielen Baumarten mit Herzwurzelsystem eine wichtige Rolle, weil besonders dieses Wurzelsystem zu einer relativ dichten Feinbewurzelung führt. Es muss aber auch auf die Nachteile der Baumarten mit allzu oberflächlicher und zu dichter Feinwurzelentwicklung hingewiesen werden, weil sie dadurch eine grosse Konkurrenz, insbesondere auf Mischbaumarten, die zwar eine gleich

tiefe aber lockerere Bewurzelungsdichte aufweisen, ausüben.

In dieser Hinsicht ist beispielsweise an die von unseren Vorfahren gemachten Erfahrungen mit dem Mittelwaldbetrieb zu erinnern, wonach die Buche mit ihrem oberflächlich-dichten Wurzelwerk und somit ihrem draufgängerischen Konkurrenztemperament in der Bodenbesiedlung negativ auf das Wachstum beigemischter Baumarten wirkte (Mathey 1929). Dies ist mit ein Grund, weshalb im Mittelwald die Arten mit oberflächlicher Bewurzelung und relativ diffuser Wurzeldichte, wie die Linde und Hainbuche, sich mit den tief wurzelnden Arten, wie Eiche, Ahorn, Ulme, besser vertragen.

Die Nachbarschaft verschiedener Baumarten wirkt sich auch sehr unterschiedlich auf den oberirdischen Kronenbereich aus. Dabei spielen nicht nur der Wuchsvorsprung der einen Baumart auf die andere eine Rolle, sondern offenbar auch weitere Aspekte, wie die Lichtdurchlässigkeit der Krone, eventuell ihr Ausdehnungspotential und somit die Fähigkeit, das Kronendach mehr oder weniger dicht zu schliessen. Eigene Beobachtungen zeigen, dass die Fichte in ihrer Jugend in Konkurrenz mit dem 3 - 4 m vorwüchsigen, dominierenden Bergahorn eine deutlich längere Krone bildet als im Reinbestand. Dies ist offensichtlich auf den besseren Lichteinfall durch die Ahornkrone zurückzuführen. Der Vorteil der besseren Bekronung der Fichte in der Mischung mit Laubholz wird dann bedeutsam, wenn die Fichte mit der Zeit in der Lage ist, den Höhenvorsprung der Ahorne einzuholen und ihn sogar zu übertreffen vermag (Schütz 1989). Dieses Ergebnis erklärt die statistisch nachweisbar bessere Bekronung der Fichte in Mischung mit Buche (Flury 1930; Assmann 1957), was ihr auch eine bessere Stabilität gegenüber Sturmschäden verleiht (Drescher 1965).

Auch Lichtbaumarten, wie Birke, Kiefer oder Lärche, wirken sich trotz der um mehrere Meter höheren Wuchsüberlegenheit vorteilhaft auf beigemischte Arten aus. Hingegen erweisen sich exklusive Baumarten, wie z. B. Roteiche, als deutliche Bedränger.

Die bessere Lichtdurchlässigkeit der Kronen bestimmter Baumarten, wie z.B. bei der Lärche oder Kiefer, kann sich sehr günstig auf den Mineralisierungsprozess der Streu auswirken und somit auf die Nährstoffversorgung der Böden. Der Einfluss der Streu auf den Boden darf nicht nur unter dem Blickwinkel der Streuart und ihrer Abbaubarkeit betrachtet werden, sondern alle für die Mineralisierung günstig wirkenden Faktoren, wie Wärme und Feuchtigkeit, müssen mitberücksichtigt werden. Es konnte gezeigt werden, dass eine für ihre schlecht abbaubare Streu bekannte Baumart, wie z. B. die Lärche, in relativ günstigen Klimaverhältnissen in der Südschweiz diesen Nachteil dank guter Lichtdurchlässigkeit und deshalb günstigerem Wärmehaushalt mehr als wettmachen konnte (Conedera 1984).

SCHLUSSFOLGERUNGEN

Diese Betrachtungen zeigen, dass es im Waldbau durchaus möglich ist, die fördernde Wirkung von Mischungen, selbst in sehr feiner Form, mit Erfolg auszunützen. Immerhin muss man vor der Komplexität der Phänomene und einer übereilten Euphorie warnen. Bei der rückblickenden Beurteilung der Umsetzung

der Ideen zur Förderung des Mischwaldes in die Praxis vom grossen K. Gayer (1886), kommt Burschel (1987) zu einem eher düstereren Fazit.

Ohne die ständige Ueberwachung solcher komplexen Systeme, wie Mischwälder, durch waldbaulich erfahrene und sachverständige Fachleute und den entsprechenden korrigierenden Steuerungseingriffen besteht die Gefahr der Entgleisung des Vorhabens, weil in der Natur die Entmischungskräfte meistens wirksamer sind, als die für die Mischung förderlichen Kräfte. Mischwald kann somit nur unter relativ pflegeintensiver Aufsicht voll zum Ausdruck kommen, ausser in sehr speziellen Fällen. Diese Notwendigkeit zwischen Pflegeintensität und feinen Mischungen dient der Förderung der Vielartigkeit und Vielfältigkeit im Wald und wird leider seitens des Naturschutzes und den sogenannten "Grünen" noch nicht immer richtig erfasst. Sie hätten aber ein Interesse daran!

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DIE LIBANONZEDER (Cedrus libani A. Rich): VERBREITUNG, WACHSTUM UND WALDBAULICHE BEHANDLUNG

Hüseyin Aksoy

Professor Dr.

Forstliche Fakultät der
Universität Istanbul, Türkei

FDC: 174.7 Cedrus libani A. Rich: 18

ZUSAMMENFASSUNG

Cedrus libani-Wälder wurden fast 5000 Jahre lang geplündert und beinahe ausgerottet. Heute befinden sie sich nur in der Süd-Türkei auf Taurus in der mediterran-montanen Stufe, sowie ein kleineres Areal in Syrien und Libanon. Vorherrschende Grundgestein der Zedernwälder auf Taurus sind verschiedene Kalkformationen. Sie stocken dort vier verschiedene Standortstypen: 1.flache bis mässig geneigte Hangschuttstandorte mit stabilem Oberboden, 2.mässig geneigte Schutthänge mit teilweise instabilem Rollschutt, 3.steile Schutthänge mit lockerem, labilem Oberboden, 4.rutschungsstabile Blockstandorte. Die Zedernwälder müssen je nach Standortstyp waldbaulich verschieden behandelt werden.

GESCHICHTE (Mayer-Sevim 1958, Hafner 1965)

Der älteste Bericht über Zeder stammt aus der Zeit des Pharao Snefru (um 2750 v. Chr.), in dem erzählt wird, dass vierzig Schiffe, beladen mit Zedernstämmen vom phönizischen Gubla (Byblos) nach Aegypten tranportiert wurde, um Schiffe zu bauen und die Türen des Königspalastes zu machen. Der um das Jahr 2401 v. Chr. lebende Fürst Gudea von Lagasch im südlichen Mesopotamien bezog von Hamanu (Amanusgebirge oder Antilibanon) für seine Bautätigkeit Zedernstämme von 25-30 m Länge. Schon von der Inbesitznahme durch Israel in der Zeit von 1550-1251 v. Chr., als Palestina ununterbrochen ägyptischer Provinz war, wurden mit Zwangsarbeitern Kahlschlag in den Zedernwäldern des Libanons durchgeführt. Beim Bau der Tempel von Theben, Karnak und Memphis fand Zedernholz Verwendung. In Aegypten wurden manche Mumiensärge für Pharaonen und hohe Beamte aus Zedernholz gefertigt. Bei den Aegyptern war das Zedernholz, wegen seines aromatischen geruches und seiner Farbe für Luxus- und Kultbauten, sowie zum Räuchern besonders gesucht. Die Phönizier verwendeten das Zedernholz als Tragbalken für Tempel, Paläste, Schifsbauten, Masten, Häuserbau, Türen, Bretter, Bohlen und für häusliche Gebrauchsgegenstände.

Die Könige David (1000-960 v. Chr.) und Salomon (960-927 v. Chr.) verwendeten zum Bau ihrer Paläste in verschwenderischer Fülle Zedernholz. Beson-

ders beim Bau des Tempels und der königlichen Paläste unter Salomon fand Zedernholz Verwendung für Dachkonstruktionen, Säulen, Wände, Schindeldach, Täfelung des Altars und zum Bau des Chores. Bei dem erheblichen Holzbedarf für diese grossen, 20 Jahre dauernden Bauten vollzogen sich die Nutzungen in Exploitationsform, wie aus den Verhandlungen Salomons mit Hiram, dem König von Tyrus in Libanon hervorgeht, da 30.000 Arbeiter aus Israel in Schichten zu 10.000 in Zedernwäldern Libanons Frondienste leisteten. Um 700 v. Chr. musste der assyrischer König Sanherib die Nutzungen im innersten Libanon durchführen. Die ehemals dichten Zedernwälder des Libanons waren schon von Blössen durchzogen. Gewaltige, tagelange Waldbrände haben weiter zur Verwüstung beigetragen. Während der Herrschaft von Nebukadnezar, setzte man die Nutzungen für Mesopotamien fort und verwendete Zedernholz beim Bau von Palästen und Stadttoren.

Alexander der Grosse fand 333 v. Chr. den südlichen Libanon ohne verwertbaren Holz und konnte nur aus dem abgelegenen Anti-Libanon genügend Bauholz für den Bau von 500 Schiffen gewinnen. In früherer Zeit wurde Zedernholz auch nach Kleinasien exportiert und beim Bau des Dianatempels in Ephesus verwendet. Auch in römischer Zeit wurden noch Zedernbalken vom Libanon herabgeschafft. Plinius rühmt die unvergängliche Dauer der Hochzeder und erwähnt ihre Verwendung beim Flottenbau in Syrien und Aegypten, für Götterstatuen und die über 400 Jahre beständige Dachkonstruktion des Dianatempels.

Der römische Kaiser Adrianus I. hat im Jahre 200 v. Chr. ein Gesetz erlassen, das den Schutz der Zeder, Kiefer, Tanne und Wacholder sichern sollte und die Nutzungen nur für Verteidigungszwecke erlaubte. Um die Zeitwende wurden die Zedernwälder Libanons bis auf geringe Reste zerstört, die in der Folgezeit auch durch Weideschäden weiter zurückgedrängt wurden. Nach einem 5000 Jahre andauernden Raubbau hat die Zerstörung der Zedernwälder in Libanon in den ersten drei Jahren des ersten Weltkrieges ihren Höhepunkt erreicht, in denen über die Hälfte des Zedernvorrates für den Eisenbahnbau und für Brennholz genutzt wurde. Heute stocken auf dem Libanon einige Reste der ehemals ausgedehnten Wälder von etwa 2000 ha.

Nachdem die Zedernwälder des Libanon abgeholzt waren, ging von den Zedernwäldern des Taurus Schiffbauholz bis nach Aegypten. Theophrast erwähnt in seiner Naturgeschichte als Standort der Zeder Phrygien (Afyon, Isparta, Eğridir). Er berichtet von der Hochzeder aus den kilikischen Bergen, die von ungeheueren Wäldern bedeckt waren. Nach Plinius wächst die Zeder auf den Gebirgen von Lycien (Zwischen Antalya und Fethiye) und Phrygien, nach Strabo in Cilicien.

Der Botaniker Kotschy, der um die Mitte des 19. Jahrhunderts das Einzugsgebiet des Tarsus-Flusses (Cydnus) bereiste, fand in den Gebirgslagen oberhalb von Gülek und Namrun herrliche Eichen- und Zedernwälder. Er und v. Moltke berichteten von Schlägerungen in dem Gebiet. Als die Aegypter nach 1832 Cilicien vorübergehend in Besitz nahmen, führten sie jährlich 10.000 der mächtigsten Stämme aus den Wäldern des Taurus zu den Schiffswerften in Alexandrien.

BOTANISCHES

Von der Gattung Cedrus existieren heute vier geographisch differenzierte Arten, nämlich Cedrus deodara im Himalaya, Cedrus atlantica im nordafrikanischen Atlasgebirge, Cedrus brevifolia auf Zypern und Cedrus libani im Libanon, Syrien und in der Südtürkei (Coode-Cullen 1965, Krüssmann 1972; Yaltırık 1988). Nach Arbez-Ferrandes-Uyar (1978) unterscheidet sich die Libanonzeder von Cedrus atlantica und Cedrus deodara durch grössere Nadeln, geringe Nadelanzahl pro Rosette, einen langen Seitenfortsatz und geringere Streifen auf den Stomata.

Aytuğ (1981) untersuchte Pollen von vier Zedernarten nach verschiedenen Eigenschaften. Er kam zum Schluss, Cedrus deodara sei dem Urart am ähnlichsten und älteste Art. Für Gaussen (1964) dagegen ist der älteste Zedernart Cedrus atlantica.

Nach Kantarcı (1982 a,b) gibt es in der Türkei verschiedene Ökotypen der Zeder, die sich besonders nach Nadelfarbe (dunkelgrün, graugrün, blau und silbergrün, frischgrün, hellgrün, sehr hellgrün, goldgelb) und Astform (mit hängenden Asten, Kandelaberform, Zwergform) unterscheiden.

In Anlehnung an Dallimore-Jackson (1966) gibt Yaltırık (1988) verschiedene Kultivare von Libanonzeder: cv. aurea mit goldgelben, cv. glauca mit blaugrünen Nadeln, cv. aurea prostrata mit goldgelben Nadeln sowie zwerg- und krüppelhafter Form, cv. comte de dijon mit breit-kegelförmiger Krone und zwerghafter Form, cv. decidua mit besonders gegen Ende-Winter abgefallenen Nadeln.

Senitza (1989) stellt unterschiedliche Ausbildung der Kronen von Jung- zu Altbäumen fest, die nach dem Standort differenziert sind. Zedern zeigen nach dem Stagnieren des Höhenwachstums (ca. 150-200 J.) eine typische Umbildung der Krone von einer jugendlichen Spitzkrone mit dichter Beastung zu einer Schirmkrone ohne erkennbaren Wipfeltrieb, mit stockwerkartig übereinanderliegenden waagerechten Astebenen.

VERBREITUNG

Ausserhalb der Türkei kommt Zeder in Libanon und Syrien stark zersplittert auf eine Gesamtfläche von 2000 ha vor. Cedrus libani - Wälder befinden sich heute in der Türkei, auf Taurus auf eine Fläche von 99.325 ha, aber auch zwei kleine Relikte in Nordanatolien bei Erbaa und Niksar. Dieses Verbreitungsgebiet ist mit einer Zedernwaldstufe (1000/1400-2000/2200 m) charakterisiert (Quézel-Pamukçuoğlu 1973).

Im Mittel- und Osttaurus auf Gipfel- und tiefere Kuppenlagen (1600-1900 m) mit Kalksteinbraunlehm über der Schwarzkiefernstufe (Flysch 1450 m) ist Zedernwald (Abieti-Cedrion) beschränkt. Die Zeder wird im Tannenareal auf Steilabbrüche, felsige Reliktstandorte und hochmediterrane trockenere Standorte sowie Gipfellagen abgedrängt. Der für den Ost-Taurus endemische Thlaspi cataonicum-Cedrus libani-Wald besiedelt auf Kalk (Flysch) einen Vegetationsgürtel zwischen 1600-1900 m. Der endemische Quercus petraea ssp. pinnatiloba-Cedrus libani-Wald besiedelt im Amanus zwischen 1400-1800 m auf Kalk, Quarzit

und Grauwacke felsige Standorte. Ungenügend bekannter Sesleria anatolica-Cedrus libani-Wald tritt im Mittel-Taurus infolge grosser Konkurrenzkraft der Tanne nur kleinflächig auf.

Im Westtaurus, westlich von Antalya-Burdur auf Kalk und Dolomit dominieren die am besten erhaltenen Zedernwälder (Lonicero-Cedrion) des Taurus. Durch das Fehlen von Abies cilicica und nur fragmentarisches Vorkommen von Pinus nigra auf Extremstandorten besitzt die Zeder eine weite ökologische Amplitude. Im Westtaurus weit verbreiteter, lokal differenzierter Alliaria officinalis-Zedernwald besitzt drei ökologisch differenzierte Untereinheiten (Akman-Barbéro-Quézel 1979). Paeonia turcica-Subassoziation ist überwiegend auf Schattseiten an humiden Talstandorten bzw. Kalksteinbraunlehmböden (verbraunten Rendzinen) entwickelt. Festuca varia-Subassoziation stockt auf sonnseitigen Kalkfels-Standorten mit gering entwickelten Rendsinen und Xerorendsina im Bereich der oberen Waldgrenze. Cerastium fragilimum-Subassoziation tritt hochmontan auf gering geneigten, oberflächlich schwach versauerten tiefgründigen Böden (Terra fusca-Parabraunerde) auf. Oryzopsis holciformis-Zedernwald kommt tiefmontan (1400-1600 m) auf sonnseitigen Standorten mit verbraunter Moder-Rendzina vor. Vicia cracca ssp. stenophylla-Zedernwald stockt von 1450-1950 m auf metamorphem Kalkstein mit Mull-Rendzina.

Im mittel-subeuxinischen Zwischengebirge bei Erbaa-Tertepe von 700/1000-1300 m in Süd- und Ost-Exposition besiedelt submeditterraner Pinus sylvestris-Pinus nigra-Cedrus libani-Reliktwald mässig steile Hänge auf Schiefer und Andesit.

STANDORTSCHARAKTERISTIK

B i o k l i m a (Kantarcı 1982 a, 1984, 1985)

Die west-südwestlichen feucht-warmen Depressionswinde vom Mittelmeer und kalt-trockene Luft aus dem Inneranatolien sind Hauptklimaeffekte. Aus diesen Einflüssen entstehen je nach den topographischen Verhältnissen unterschiedliche Klimatypen. Der Südabfal des Taurus im Zedernareal ist humid (2000 mm) bis semihumid (1000 mm). Leelagen im Zwischentaurus können auch tiefmontan schon semihumid-semiarid sein (700-1000 mm). Am steppennahen Nordabfall ist an der unteren Verbreitungsgrenze der Zeder mit geringen Niederschlägen (500-700 mm) und semiariden Klimacharakter (3-4 Trockenmonate im Sommer) zu rechnen, bei einer Jahresmitteltemperatur von 9-13° C in Hochlagen mit kalten bis sehr kalten, schneereichen Wintern.

Im Hauptareal (1500-2000 m) der Zeder herrscht ein mediterran-montaner Klimacharakter. Im Westtaurus hat sie unter 1300/1400 m submediterraner kontakt durch einzelne Hartlaubbäume. Aufgelockerte Cedrus-Juniperus excelsa-Mischbestände in 2000-2200/2300 m gehören zur kulminalen Bergstufe. man kann zwei fragmentarische Höhenstufen unterscheiden. Tiefere Zone: Laubbäume fehlen (Ausnahme Quercus libani/trojana), meso-xerophil mit reichlich Therophyten der Querco-Cedretalia. Höhere Zone: lokal wechselnd mit typischem Unterwuchs: Quercus petraea ssp. pinnatiloba (Ost-Taurus), Populus tremula, Ulmus glabra, Acer hyrcanum, Acer platanoides. Lokal (1500-1800 m) sogar Ostrya carpinifolia bzw. Carpinus orientalis bei maritimem Einflus (Teke Dağı und Tahtalıdağ bei Antalya). Xerophile bis Substeppen-Standorte bei Gesell-

schaftsauflösung mit Pinus nigra und Juniperus excelsa besonders am trockenen Nordabfall.

Die ökologische Amplitude in der mediterran-montanen Stufe reicht von mesophilen-humiden Zedern-Mischwäldern über subhumide bis Xerophile, semiaride Einheiten auf jeweils typischen Standorten. Im West-Taurus ist die ökologische Amplitude der Zeder besonders gross.

G r u n d g e s t e i n u n d B ö d e n

Vorherrschende Grundgestein der Zedernwälder auf Taurus sind verschiedene Kalkformationen aus dem Mesozoikum (Eozen, Miozän, Perm, Karbon) in Form kristalliner Kalke, massiver weisser Kalke, weicher Kalke, Marmor, sowie Glimmerschiefer und Serpentin. Unter dem reliktischen Zedernbeständen in Nordanatolien dagegen kommt Olivin-Basalt vor (Sevim 1952, 1955). Im Verbreitungsgebiet der Zeder auf Taurus treten im allgemeinen Skelettreiche, karbonathaltige, stickstoffreiche, lehmig-feinsandige Böden von hoher Permeabilität und günstiger Durchlüftung auf, wobei pH-Werte zwischen 5,2 und 7,8 variieren (Sevim 1955). Zedern wachsen aber am besten in tiefgründigen, skelettarmen, spaltenfrischen Böden (Mayer-Aksoy 1986).

Im verkarstungsanfälligen Kalkgebiet dominieren tiefmontan (1000-1600 m) Terra rossa und Terra fusca, hochmontan (1600-2000 m) verbraunte Terra fusca bis Fahlerde-Parabraunerde (Kantarcı 1982 a); häufig sind auch Übergangsformen zu Rendzinen, wie braune Rendzina, Mull-Rendzina und Xerorendzina.

WALDBAU

G r u n d l a g e n

Die männlichen Blüten erscheinen im Juli und reifen im September. Die weiblichen Blüten kann man erst im September sehen. Sie entwickeln im folgenden Jahr sehr rasch und haben nach 14-15 Monaten im Herbst die Grösse von reifen Zapfen. Im 2. Jahr reifen sie bis Oktober aus. Im 28. Monat öffnen sich die Schuppen je nach Regenfall im Oktober oder November. Die Zapfen zerfallen in 2-3 Monaten völlig. Reiche Samenjahre erfolgen in 3-5 Jahren. Masse der Zapfen sind 84,6 (54-135) x 50 (38-66) mm und Gewicht 85 (30-240) g. Kornmasse sind 11,8 (8,5-14,5) x 5,4 (3,8-7,0) mm und 1000-Korngewicht 76,4 (51,1-100,3) g. Für Überwindung von Keimhemmung ist es zweckmässig, die Samen 30-60 Tage kalt-nass vorzubehandeln (Odabaşı 1967).

Die Zeder ist keine extreme Lichtbaumart, nahezu eine Halblichtbaumart, da sie sich in grösseren Lücken verjüngt und unter lichtem Schirm 5/6-8/10 in extremen Fällen sogar 30-70 Jahre Druckstand verträgt (Sevim 1953, Saatçioğlu 1976, Kalıpsız-Eler 1984).

In seiner Doktorarbeit im Zedernversuchswald Çamkuyusu (Westtaurus) unterscheidet Senitza (1989) vier Standortstypen. Standortstyp 1: stabil, Neigung 0-17°, flache bis mässig geneigte Hangschuttstandorte mit stabilem Oberboden. Standortstyp 2: mässig labil, Neigung 18-27°, mässig geneigte Schutt-

hänge mit teilweise instabilem Rollschutt. Standortstyp 3: labil, Neigung mehr als 28°, steile Schutthänge mit lockerem Oberboden; extrem gefährdet durch Steinschlag, Rollschutt und Schnee. Standortstyp 4: Blockstandort, dichter, blockartig verwitterter Kalkfels bildet unabhängig von der Neigung rutschungsstabile Standorte.

Je nach Standortstypen der Zedernwälder schlägt Senitza (1989) waldbauliche Behandlungtypen vor. Bei den Standortstypen 1 und 2 kann die Bestandesbehandlung auf Wirtschaftswald mit maximaler Wertleistung ausgerichtet sein. Für Zieldurchmesser von ca. 40 cm (30 cm) BHD und einem Entwicklungsstadium, das der mittleren bis späten Optimalphase entspricht, ergeben sich Umtriebszeiten zwischen 120 und 170 (200) Jahren je nach Bonität (I-V). Auf Standortstyp 3, müssen alle Massnahmen auf die Erhaltung der meist lockeren Bestände und ihre rechtszeitige Verjüngung ausgerichtet sein. Diese Bestände sind als typische Bodenschutz-, Steinschlag- und Lawinen-Schutzwälder anzusprechen. Bei dem Standortstyp 4, wegen seiner geringen Ausdehnung und seiner forstlichen und botanischen Einzigartigkeit kann die Bewirtschaftung durch möglichst differenzierte, nur kleinflächige Eingriffe, die optimale Ertragsfähigkeit nutzen und gleichzeitig durch Erhaltung der unregelmässigen Bestandesstruktur und den Überhalt von Altbäumen Naturwaldcharakter bewahren.

V e r j ü n g u n g (Boydak 1986; Kantarcı 1987 a, b; Senitza 1989)

Für die natürliche oder künstliche Verjungung der Zeder ist besonders Feuchtigkeitsversorgung entscheidend. Durch die Trockenzeit bis zum Spätherbst trocknen die obersten Bodenschichten aus. Deswegen ist Speicherung des Winterniederschlags in den spaltengründigen Böden ausschlaggebend für Verjüngung. Bei der Pflanzung bereiten sehr skelettreiche oder spaltengründige Böden auf Karstflächen grösste Schwierigkeit und hohe Ausfälle sind häufig. Für die Nachbesserung der natürlichen Verjüngungsflächen empfiehlt Saatçioğlu (1979) Lochpflanzung. Nach Güven (1975) ist die günstigste Pflanzzeit für eine Höhenlage von 1500-1600 m im Herbst November und im Frühjahr April. Er empfieht ausserdem für seichtgründige Standorte kleine Ballenpflanzen (2/0). Nach Boydak (1986) ist die günstige Pflanzzeit auf Nord-Hängen im Herbst, auf Süd-Hängen im Frühjahr.

Wenn nach einem seltenen Samenjahr 1-2 feuchte Jahre folgen, bewährt sich Saat gut. Saatçioğlu (1979) empfiehlt 12-15 kg/ha Saatgut. Bei Streifenkahlschlag beträgt die empfohlene Saatgutmenge 8/10-10/12 kg/ha (Boydak 1986). Bei der Ausbringung von Samen und Zapfenschuppen zusammen empfiehlt Boydak (1986) 100-200 kg/ha (ca. 10-20 kg/ha reine Samen).

Bei der Verjüngung der Zeder bewährt sich kontrolliertes Schlagbrennen gut (Kantarcı et al. 1986). Dadurch werden Streuauflagen und die Bodenvegetation rasch mineralisiert, sowie deren Samen vernichtet und die Keimung durch Nährstoffzufuhr begünstigt. Keimlinge und Jungpflanzen haben kräftige Benadelung, grössere Trieblängen und geringere Ausfälle, auch nach Trockenperioden.

Nach den Ergebnissen der Naturwaldanalyse beurteilt Senitza (1989) Verjüngungsverfahren nach den Standortstypen. Im Wirtschaftswald (Standortstyp 1 und 2) erfolgt die Bestandeserneuerung gruppenweise in Zweischichtigen

Verjüngungsphasen. Die Bewirtschaftung unterbricht den natürlichen Entwicklungszyklus in der mittleren bis späten Optimalphase. Bei solchen Beständen sollte ein möglichst hoher Anteil von Naturverjüngung ausgenutzt werden. Dazu eignen sich kombinierte Verfahren (Boydak 1986) von Schirmschlag bzw. Streifenkahlschlag mit Schlagbrennen. Auf flachen Standorten mit unzersetzte Streuauflage sind ergänzende Massnahmen, wie plätzeweise Schlagbrennen oder Bodenverwundung sowie Saat notwendig, um Verjüngungserfolg zu grantieren. Hangparallele Rillensaat, die einerseits geringeren Saatgut bedarf und Pflegeaufwand erfordert, andererseits durch eine ungestörte Streuschicht zwischen den Rillen Verdunstungschutz bietet, bewährt sich auch gut.

Wegen der Gefährdung von Verjüngung auf Steilhängen durch Steinschlag und Schnee erfordern Schutzwaldstandorte (Standortstyp 3) spezielle Verfahren. Um eine dauernde, schutzwirksame, stabilisierende Bestockung zu erhalten, muss die Verjüngung frühzeitig und kleinflächig eingeleitet werden. Bei den meist lockeren bis räumdigen Beständen können sich Verjüngungsgruppen ungehindert entwickeln. Ernte soll mit dem Ziel der Strukturpflege, baum- oder gruppenweise erfolgen. Zur Ergänzung und Unterstützung der spärlichen Naturverjüngung kann kleinflächige Pflanzung an geschützten Kleinstandorten unterhalb von Stöcken, Felsbändern und stabilen Bestandesteilen empfohlen werden.

Den kleinflächig wechselnden Bestandesstrukturen auf Blockstandorten (Standortstyp 4) kann eine möglichst flexible waldbauliche Behandlung mit femelschlagartigem Verjüngungsverfahren gerecht werden.

B e s t a n d e s p f l e g e (Kantarcı 1987 a, b, 1988; Senitza 1989)

Bei den Pflegeeingriffen zur Erreichung der waldbaulichen Zielsetzungen müssen unterschiedliche Bestandesstruktur und Entwicklungsdynamik berücksichtigt werden. Im Wirtschaftswald (Standortstyp 1 und 2) begründen Strukturanalysen von Dickungs- bis Stangenholzstadien die Notwendigkeit frühzeitiger Pflegeeingriffe. Bei extrem stammzahlreichen Jungwüchsen (15.000 - 30.000 Stk/ha) kann die Individuenzahl bereits bei einer Höhe von 2-3 m auf ca. 2.000-3.000 Stk/ha gesenkt werden. Kantarcı (1987 b) berichtet von einer Individuenzahl von 93.296 Stk/ha im Alter von 5 Jahren auf eine Verjüngungsfläche durch Schlagbrennen und Saat. Er empfiehlt die Individuenzahl im 5. Jahr auf 8-10/12 Tausend, sogar bei der 2. Jungwuchspflege auf 3-4 Tausend zu senken, um Wurzelkonkurrenz möglichst auszuschalten.

Im Stangenholzstadium sinken soziologisch schwächere Bäume bei zunehmender Konkurrenz stark ab und bilden eine zweite Bestandesschicht. Auch die Untersuchungen von Kalıpsız und Eler (1984) bestätigen dieses starke Zurückfallen von Beherrschten und Unterdrückten bei Höhen und Durchmesserzuwachs. Nach Senitza (1989) soll am Ende der späten Initialphase eine gezielte Durchforstung eingesetzt werden. Bei dieser Erstdurchforstung sollen vor allem Mitherrschende, die qualitativ beste Herrschende bedrängen, entnommen werden. Dabei werden auch schlecht vitale und absterbende Unterdrückte und Beherrschte entnommen. Der Eingriff muss ca. 10-15 Jahre später mit schwacher Auslese und mässiger Nebenbestandsdurchforstung wiederholt werden. Folgende 10-15 Jahre periodische Durchforstungen können allmählich auf Niederdurchforstung und Waldhygienische Massnahmen beschränkt bleiben.

Auf Schutzwaldstandorten (Standortstyp 3) soll die Bestandespflege unbedingt auf Erhaltung und Stabilisierung der Bestockung abgestimmt werden. Sämtliche Pflegemassnahmen sollen die Verjüngung fördern und schützen. Bei den niedrigen Stammzahlen kann auf Durchforstungen meist verzichtet werden.

Auf den Blockstandorten (Standortstyp 4) kann auch wie auf Standortstyp 1 und 2 vorgegangen werden.

HOLZEIGENSCHAFTEN

Nach den Untersuchungen von Berkel (1954) an Libanonzedernholz haben 57-71 Jahre alte Stämme 20-45 % hell-gelblich bis rötlich-braunes Kernholz sowie schwach rötliches und ziemlich breites Splintholz. Echte Harzkanäle fehlen, gelegentlich treten in Reihen grosse Harzzellen auf. Jahrringbreiten sind im Durchschnitt 3,49 mm (Extremwerte 0,4-10,0 mm), wobei Spätholzanteil zwischen 2,5 und 62,5 % (häufigste Wert 12,5 %) liegt. Raumgewicht ist darrtrocken und durchschnittlich 0,487 (0,380-0,620) g/ccm (nach Erdin (1985) 0,476 g/ccm), lufttrocken und durchschnittlich 0,523 (0,416-0,656) g/ccm (nach Erdin (1985) 0,517 g/ccm). Raumdichtezahl liegt bei 437 (338-576) kg/fm (nach Erdin (1985) bei 433 kg/fm). Die Druckfestigkeitswerte liegen darrtrocken bei 716 (512-967) kg/ccm, lufttrocken bei 450 (240-600) kg/ccm. Zugfestigkeitswert ist lufttrocken 16 (8-22) kg/ccm. Biegfestigkeitswert liegt lufttrocken bei 768 (450-1250) kg/ccm. Faserlänge ist 3-4 mm, Faserbreite dagegen 0,012 mm.

Libanonzedernschnittholz lässt sich leicht und schnell trocknen. Es ist nicht sehr empfindlich für Rissbildung, Formänderung und Verschalung bei der Trocknung. Bei der Trocknung nimmt der Harzaustritt mit zunehmender Temperatur zu und die Holzfarbe wird dunkler (Kantay 1978).

Libanonzedernholz enthält im Durchschnitt 69,51 % Holozellülose und 29,86 % Lignin, wobei der Aschenanteil des Holzes bei 0,49 % liegt (Önal-Ferah-Sözen 1989).

SCHAEDEN

Wichtigster Zedernschädling in den Zedernwäldern der Türkei ist Acalla undulana Wlsghm. Im Jahre 1944 wurden die Zedernbestände auf eine Fläche von 1200 ha im West-Taurus von Acalla undulana kahlgefressen. Befallen waren besonders Stangenhölzer und Altbäume. Die Raupen von Acalla undulana leben teils frei, teils in sackähnlichen Gespinsten an den Kurztrieben. Zedernnadeln werden meist randlich angefressen, zum Teil unterseits ausgehöhlt oder völlig abgefressen. Sie vergilben rasch und fallen teilweise ab. Bei starkem Auftreten wechseln Raupen ihre Frassbäume von Zeit zu Zeit und verbreiten sich dabei durch Gespinstfäden mit dem Wind (Acatay 1952). Später traten Kalamitäten auf grössere Flächen. Die befallene Fläche erhöhte sich im Jahre 1955 auf 4000 ha im Jahre 1964 sogar auf 36600 ha. Letzte grosse Kalamität trat im Jahre 1969 auf eine Fläche über 60000 ha (Ekici 1970). Im Zedernversuchswald Çamkuyusu (West-Taurus) beobachtete Senitza (1989) eine grossflächige Acalla undulana-Schädigung bei überwiegend gleichförmigen dichten Stangenhölzern. Ekici (1971) stellte weitere weniger wichtige Zedern-

schädlinge im türkischen Zedernareal fest: Orthotomicus erosus Woll. Phloeosinus acatayi Schedl., Crypturgus cirereus Herbest, Xyloterus lineatus Olivier, Melanophila delagrangei Abeille, Anoxia orientalis Kryn. Eriophyes Cedri Acatay.

Auch Hasenschäden durch Verbiss von Haupttrieb können bei den Saatflächen auf Südhängen einen Verlust von 40 % der Verjüngung erreichen (Akan 1979, Kantarcı-Parlakdağ-Pehlivan 1986).

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ECOPHYSIOLOGIE DES CEDRES (CEDRUS SP.) :
CONSEQUENCES POUR LA SYLVICULTURE

Gilbert AUSSENAC et Jean-Marc GUEHL

Laboratoire de Bioclimatologie-Ecophysiologie
Station de Sylviculture et de Production
I.N.R.A. NANCY
F-54280 CHAMPENOUX, France

FDC: 174.7 Cedrus spp.: 181.2/.3: 181.65

SUMMARY

Results obtained in our laboratory on the ecophysiological functioning of the different Cedrus species in the last years allow to draw a global picture of their adaptation features to drought, temperature and high atmospheric CO_2 concentrations as compared to other coniferous or broadleaved species. Cedrus atlantica is characterized by low values (< -0.30 MPa) of critical predawn water potentiel (potential at which stomata are completely closed) which is in well agreement with the low value of the turgor loss potential (-3.6 MPa). The different Cedrus species are able to maintain significant photosynthetic activity (10 % of the maximum values) down to predawn water potentials as low as -3.5 MPa, or even lower, depending on the species. Elongation growth of C. atlantica is stopped at -2.0 MPa, while that in the other species studied is stopped at significantly higher values. However Cedrus atlantica does not exhibit a very efficient stomatal control of water losses and a main feature of its drought adaptation is made up by efficient root growth and soil prospection ability. Cedrus atlantica and Cedrus libani are characterized by lower winter photosynthetic capacities than Douglas fir and by a high sensitivity of CO_2 assimilation and elongation growth to low temperatures. Growth enhancement due to atmospheric CO_2 enrichment is higher in Cedrus atlantica than in Pinus nigra ssp. Laricio var. Calabrica.

Keywords : Water relations, temperature, stomatal regulation, photosynthesis, growth.

INTRODUCTION

La dénomination Cèdre recouvre quatre espèces qui occupent des surfaces inégales dans l'étage montagnard de la région méditerranéo-himalayenne : **Cedrus atlantica** Manetti au Maroc et en Algérie, **Cedrus libani** Loudon au Liban, en Syrie et en Turquie, **Cedrus brevifolia** Henry à Chypre, **Cedrus deodara** Loudon en Afganistan et Himalaya occidental. Alors que les trois

premières espèces sont actuellement liées au climat méditerranéen, Cedrus deodara croît sous des climats plus divers. Pour ce qui concerne Cedrus atlantica, bien que l'on manque de données climatiques précises, on peut considérer qu'il s'agit d'une espèce qui, dans son aire d'origine, pousse à des altitudes variant de 1400 à 2200 m, avec des pluviométries annuelles de l'ordre de 500 à 1500 mm. Cedrus libani se rencontre à des altitudes comprises entre 1400 et 1800 m, la pluviométrie variant de 750 à 2000 mm, avec une sécheresse estivale très longue pouvant atteindre six mois. Cedrus brevifolia n'existe qu'à Chypre, à des altitudes comprises entre 1400 et 1600 m ; les conditions climatiques sont mal connues, mais se caractérisent par une sécheresse estivale très prononcée. Cedrus deodara, dans l'Himalaya s'étage depuis des altitudes de 1200 m jusqu'à 3500 m et l'on peut distinguer, suivant le degré de sécheresse, des forêts de Deodar humides, sèches et arides.

Il y a déjà maintenant plus d'un siècle qu'ont été entrevues les possibilités d'acclimatation des Cèdres en dehors de leurs aires d'origine. En France, la réussite des reboisements du Mont Ventoux (Vaucluse) et du Rialsesse (Aude) font que cette espèce jouit actuellement d'un intérêt certain auprès des reboiseurs. Les introductions effectuées dans différents pays montrent qu'en fait les Cèdre peuvent se développer vigoureusement dans les conditions climatiques différant de leurs aires d'origine. Ainsi, à bien des égards, l'aire naturelle actuelle des Cèdres n'apparaît pas totalement en rapport avec les aptitudes écophysiologiques de cette essence. Afin de préciser l'aire potentielle d'utilisation des Cèdres, des études écophysiologiques, portant notamment sur la réponse à la sécheresse, ont été entreprises sur différentes espèces et provenances.

RELATIONS HYDRIQUES, TRANSPIRATION ET PHOTOSYNTHESE

Le Cèdre (C. atlantica) résiste à des stress hydriques très importants, les mesures effectuées montrent qu'il peut supporter des dessèchements atteignant un potentiel hydrique de base de -4.0 MPa, et retrouver après réhydratation du sol une activité transpiratoire et photosynthétique normale. Par beau temps, même avec un sol bien alimenté en eau, le potentiel hydrique des rameaux de Cèdre peut s'abaisser fortement au cours de la journée et atteindre -3.0 MPa (Figure 1). Au cours du développement d'une sécheresse édaphique, une valeur critique du potentiel hydrique est celle caractérisée par l'égalité entre le potentiel de base (potentiel mesuré en fin de nuit) et le potentiel minimum journalier ; cette valeur seuil correspond au blocage des échanges gazeux transpiratoires et photosynthétiques. Cette valeur critique est atteinte pour des potentiels de base de -1.8 MPa pour le Pin sylvestre et le Pin noir d'Autriche et de -2.5 MPa pour le Douglas (Figure 2). Le Cèdre se caractérise par un comportement très différent de ces espèces, puisqu'à un niveau de potentiel de base de -3.0 MPa, le potentiel critique défini précédemment n'est pas encore atteint, indiquant la poursuite de la transpiration. La non existence d'un blocage transpiratoire efficace peut avoir pour conséquence des dessèchements de cimes qui confirment que le Cèdre n'est pas en mesure d'éviter des dégâts importants dans des situations de sécheresse très prononcée. Les Pins, disposant au niveau stomatique de possibilités de blocages rapides de la transpiration, sont beaucoup mieux adaptés à ces situations. Dans une étude reposant sur l'analyse des relations

hydriques à l'aide de courbes pression-volume, **GUYON** (1987) estime, dans le cas de **Cedrus atlantica** (provenance Ventoux), à -3.6 MPa le potentiel hydrique correspondant à la turgescence nulle des tissus ; cette valeur est sensiblement inférieure à celle déterminée pour le Pin noir d'Autriche (-2.2 MPa). Ces valeurs seuils sont compatibles avec les valeurs de potentiel de base critique évoquées ci-dessus pour les mêmes espèces.

Les Cèdres maintiennent une activité photosynthétique importante, même en situation de stress hydriques élevés. Selon les espèces ou provenances, des différences importantes existent (**Figure 3**). Pour une valeur de potentiel de base de -3.5 MPa, la capacité photosynthétique de **Cedrus deodara** est de 10 % de la valeur maximale, cependant que pour les autres espèces (**C. atlantica**, **C. brevifolia** et **C. libani**) ce seuil de 10 % est atteint pour des valeurs de potentiel de base inférieures à -5.0 MPa. Par ailleurs, la provenance Sutlegen de **C. libani** se caractérise d'une part par l'existence d'une stimulation de la photosynthèse pour des contraintes hydriques modérées (maximum de la photosynthèse pour -1.5 MPa) et d'autre part par la sensibilité de la photosynthèse au déssèchement la plus faible des espèces et provenances étudiées (**AUSSENAC et FINKELSTEIN**, 1983).

L'étude des effets d'une sécheresse édaphique sur la photosynthèse à l'aide des relations entre taux d'assimilation de CO_2 et les concentrations intercellulaires en CO_2 montrent (**GRIEU et al.**, 1988) (**Figure 4a**) que la diminution de photosynthèse est essentiellement liée à l'altération des processus chloroplastiques. La conductance stomatique est affectée également de façon très sensible par la sécheresse du sol, mais n'intervient que secondairement dans la réduction de photosynthèse. Comparativement, **Pseudotsuga macrocarpa**, espèce adaptée aux conditions xériques de Californie (USA), présente une contrôle stomatique des échanges gazeux plus efficace, caractérisé par l'existence d'une phase purement stomatique entre -0.8 et -1.5 MPa (**Figure 4a**). Paradoxalement, **Pseudotsuga menziesii**, espèce des zones humides de la côte pacifique des USA et du Canada, mais à déficit hydrique estival important, se caractérise par un contrôle uniquement stomatique des échanges gazeux efficient sur une gamme de variations de potentiel (de -0.7 à -2.2 MPa) plus large encore que celle de **Pseudotsuga macrocarpa**.

Pour ce qui concerne les effets de la sécheresse atmosphérique (**Figure 4b**), les études effectuées montrent que **Cedrus atlantica** présente surtout une sensibilité au niveau des processus chloroplastiques et se différencie peu à cet égard des espèces du genre **Pseudotsuga**.

En définitive, **Cedrus atlantica** ne se caractérise pas, au plan de la sensibilité de la photosynthèse et de la régulation des échanges gazeux par une adaptation plus efficace aux sécheresses édaphique et atmosphérique qu'une espèce de zone humide telle **Pseudotsuga menziesii**. Les travaux menés par **GRIEU** et **AUSSENAC** (1988) montrent que chez **Cedrus atlantica**, et aussi chez **Pseudotsuga macrocarpa**, la résistance à la sécheresse réside en grande partie dans un développement racinaire profond et rapide (**Figure 5**).

En dehors de la saison de végétation, la capacité photosynthétique des Cèdres est affectée par les basses températures (**GUEHL et al.**, 1985). Contrairement au Douglas, qui durant les périodes hivernales de températures positives entrecoupant les épisodes froids se caractérise par un

rétablissement très rapide de la capacité photosynthétique, les Cèdres (C. atlantica et C. libani) présentent une diminution de ce paramètre progressive et irréversible à court terme (**Figure 6**). Par ailleurs, la courbe de réponse de la photosynthèse à la température (**Figure 7**) présente une sensibilité très forte aux températures inférieures à 15°C, contrairement au Douglas présentant un large domaine thermique optimal pour la photosynthèse.

CROISSANCE

Les études effectuées à Nancy (**AUSSENAC et al.**, 1981) montrent que la croissance en hauteur du Cèdre est de type monocyclique longue et peut se dérouler du début Mai à la fin Septembre. Le seuil thermique inférieur de croissance en hauteur, estimé à 6.6°C pour le Cèdre de l'Atlas (**AUSSENAC et al.**, 1981), est significativement plus élevé que celui d'autres espèces telles le Sapin de Nordmann (6.2°C), le Douglas vert (5.8°C), le Sapin pectiné (5.2°C) (**AUSSENAC**, 1975). Comparativement au Cèdre, la plupart des autres conifères ont une durée de croissance plus courte (**Figure 8**). Cette caractéristique peut apparaître comme paradoxale dans la mesure où par exemple dans le cas des sapins méditerranéens, certains auteurs estiment qu'une période de croissance en hauteur brève constitue une adaptation aux conditions de sécheresse. En fait, les études effectuées par **AUSSENAC et FINKELSTEIN** (1982), montrent que la croissance en hauteur du Cèdre ne commence à être fortement limitée que lorsque le potentiel de base atteint -1.3 MPa, et n'est totalement arrêtée qu'au delà d'un potentiel de base de -2.0 MPa. Ces valeurs sont notablement plus faibles que celles observées pour d'autres espèces résineuses ou feuillues (**Figure 9**, **AUSSENAC et LEVY**, 1983 ; **GRIEU**, 1986). Les conditions de sécheresse qui peuvent règner dans certaines cédraies françaises sont cependant susceptibles d'arrêter la croissance en hauteur du Cèdre pendant des périodes prolongées (**Figure 10**). Ce type de croissance en hauteur confère au Cèdre la capacité d'exploiter des épisodes climatiques humides (niveaux infra et interannuel), mais rend cette espèce sensible aux gelées précoces. Par ailleurs, il semble que cette caractéristique, associée à une phase de croissance racinaire intense avant le débourrement, soit susceptible de permettre au Cèdre d'exploiter plus que d'autres espèces (Pin laricio de Corse par exemple), l'augmentation de concentration atmosphérique en CO_2 comme le montrent les premiers résultats expérimentaux obtenus par **KAUSHAL** et al. (1989) (**Tableau 1**). Dans l'hypothèse d'une augmentation très probable de la concentration atmosphérique en CO_2 liée aux activités humaines, cette réponse très sensible du Cèdre, pourrait constituer un avantage certain pour cette espèce dans les prochaines décennies.

CONCLUSION

Bien que les études écophysiologiques entreprises sur les différentes espèces et provenances fassent ressortir des différences qu'il serait nécessaire de mieux analyser, il apparaît que les Cèdres ont un comportement d'ensemble typique et relativement homogène qui les différencie bien des

autres résineux. Cependant, Cedrus deodara, caractérisé par une sensibilité relativement plus grande à la sécheresse, semble se détacher des autres espèces, ce qui pourrait confirmer l'hypothèse de l'existence de deux espèces, l'une méditerranéenne (Cedrus patula avec deux sous-espèces atlantica et libani) et l'autre himalayenne (Cedrus deodara) (DEBAZAC, 1964).

Le Cèdre est une essence capable de supporter sans dommage des froids hivernaux importants, mais toutes les autres caractéristiques analysées montrent que son écophysiologie correspond à des "climats doux".

Au plan de la résistance à la sécheresse, le Cèdre est capable, par son type de croissance en hauteur, et ses capacités de photosynthèse en conditions de déficit hydrique, d'exploiter les pluviosités irrégulières à l'échelle infra et interannuelle. Cependant, le contrôle stomatique extrêmement tardif des pertes d'eau transpiratoires met cette espèce en situation difficile lors de phase prolongées (plusieurs mois) de sécheresse.

Une autre caractéristique importante du Cèdre par rapport à la sécheresse réside dans la capacité de développement d'un système racinaire profond. Ce caractère avait déjà été souligné par LEPOUTRE (1964) dans des études effectuées au Maroc. Aussi, les pleines capacités d'adaptation à la sécheresse du Cèdre ne peuvent s'exprimer que dans les situations susceptibles de permettre à cette essence d'exploiter des réserves hydriques profondes. A cet égard, il faut souligner l'intérêt des techniques de préparation du sol, en particulier le sous-solage, en zone méditerranéenne.

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FIGURE 1.- Evolution journalière du potentiel hydrique chez <u>Cedrus atlantica</u> Manetti au cours d'une journée ensoleillée dans le Mont-Ventoux. P_B, potentiel hydrique de base atteint en fin de nuit ; P_M, potentiel hydrique minimum. (D'après AUSSENAC et VALETTE, 1982).

FIGURE 2.- Evolution comparée du potentiel de base (P_B) et du potentiel minimum (P_M) en phase de dessèchement.

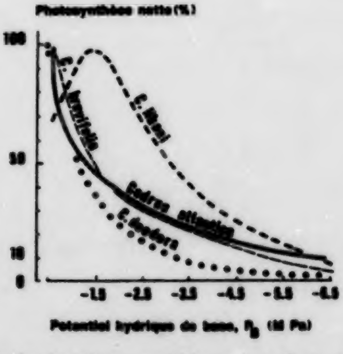

FIGURE 3.- Evolution de la photosynthèse (en % de la valeur maximale) en fonction du potentiel hydrique de base. (D'après AUSSENAC et FINKELSTEIN, 1983).

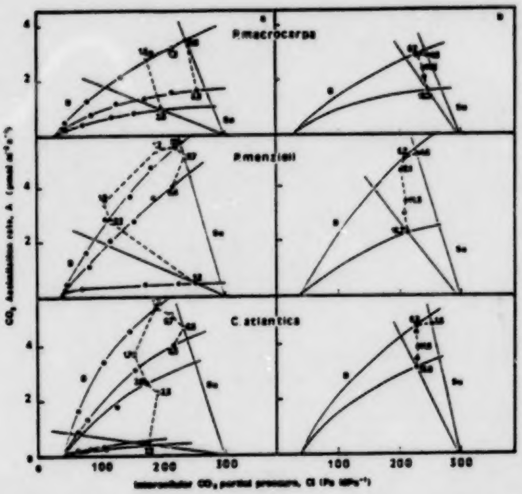

FIGURE 4.- Effets de la sécheresse édaphique (Figure 4a) et de la sécheresse atmosphérique (Figure 4b) sur l'assimilation de CO_2 (A). Les données sont représentées dans un repère (A, concentration intercellulaire en CO_2) dans lequel A est à l'intersection d'une fonction de demande (D), exprimant l'efficacité des processus chloroplastiques de la photosynthèse, et d'une fonction de fourniture (Su) exprimant les limitations diffusionnelles de fourniture du CO_2 au sites de fixation du CO_2. Le trajet des points expérimentaux lors du développement des sécheresses est représenté par les lignes en tireté. Les nombres indiqués sur la figure sont des potentiels hydriques de base en MPa (Figure 4a) et des différences de pression partielle de vapeur d'eau entre feuille et atmosphère en hPa (Figure 4b). (D'après GRIEU et al., 1988).

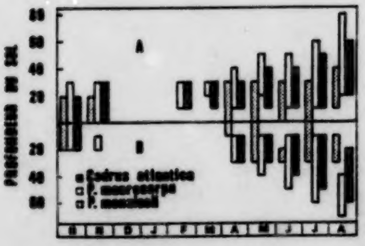

FIGURE 5.- Tranches de profondeur de sol dans lesquelles on a observé une croissance racinaire pour les trois espèces étudiées. Plants croissant en minirhizotrons. (D'après GRIEU et AUSSENAC, 1988).

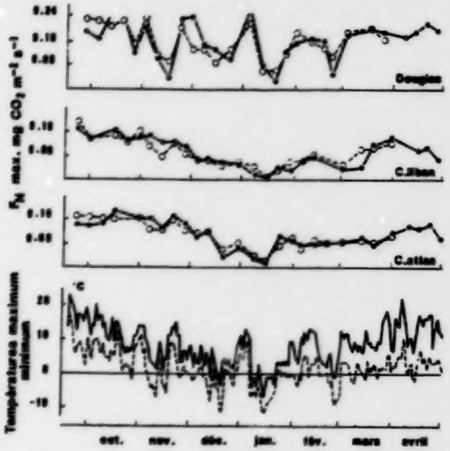

FIGURE 6.- Evolution de la capacité photosynthétique au cours de l'hiver, à Nancy, pour trois espèces de résineux, en relation avec le régime thermique (Figure du bas). Les ronds noirs représentent les valeurs réelles, les ronds blancs représentent les valeurs calculées à l'aide d'un modèle sur la base de l'histoire thermique des rameaux. (D'après GUEHL et al., 1985).

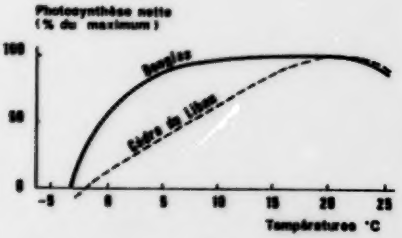

FIGURE 7.- Courbes de réponses instantanées de la photosynthèse à la température de l'air. (D'après GUEHL et al., 1985).

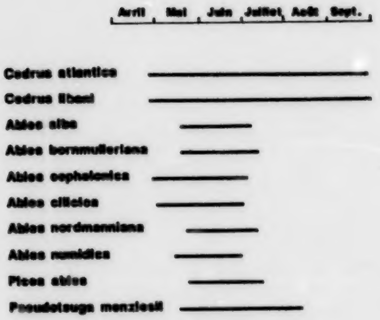

FIGURE 8.- Durée comparée de la croissance en hauteur des Cèdres et de quelques résineux à Nancy.

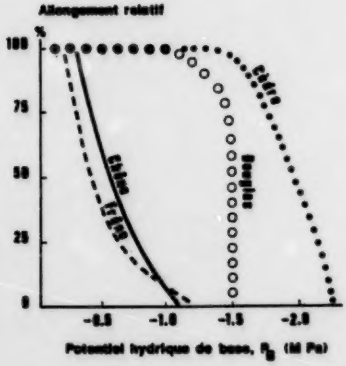

FIGURE 9.- Relations entre la croissance en hauteur et le potentiel hydrique de base (P_B) pour le Cèdre et quelques autres espèces forestières. D'après les données de (AUSSENAC et FINKELSTEIN, 1983 ; AUSSENAC et LEVY, 1983 ; GRIEU, 1986).

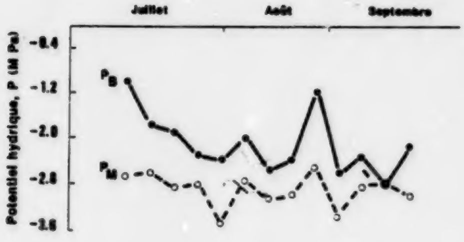

FIGURE 10.- Exemple d'évolution estivale du potentiel hydrique de base (P_B) et du potentiel Minimum (P_M) dans la Cédraie du Mont-Ventoux dans le Sud de la France. (D'après **AUSSENAC** et **VALETTE**, 1982).

Conc. CO_2 aér. (μmol mol^{-1})	Aiguilles (g)	Tige (g)	Racines (g)	Total (g)	Racines/P. (gg^{-1})
		Cedrus atlantica			
350	9.3b	9.7b	6.3b	25.3b	0.33a
800	15.4a	16.0a	10.7a	42.1a	0.34a
800/350	1.66	1.65	1.70	1.66	-
		Pinus nigra			
350	0.98a	0.22a	0.43a	1.63a	0.36a
800	1.25a	0.29a	0.57a	2.11a	0.37a
800/350	1.28	1.32	1.32	1.29	-

TABLEAU 1.- Poids de biomasse sèche des différents compartiments et rapport racines/p. aérienne de plants de Cèdre et de Pin Laricio de Corse élevés pendant 9 mois à des concentrations de 350 vpm (concentration normale) et 800 vpm. Les valeurs moyennes suivies de lettres toutes différentes sont significativement différentes ($P < 0.01$). (D'après **KAUSHAL** et al., 1989).

THE CONSUMPTION OF FUELWOOD AND ITS INCIDENCE ON THE FOREST ECOSYSTEM IN DEVELOPING COUNTRIES (1)

Mohammed ELLATIFI
Principal Engineer
Forest service
P.O. Box 12507
CASABLANCA 01
MOROCCO

FDC : 831.1: 914

SUMMARY

In the developing countries, the gap between fuelwood supply and demand is very wide. Morocco is in the same situation : the deficit between supply and demand surpasses 12 million m3 per year . In a first time a quantification of the fuelwood consumption was conducted in the city of Casablanca. This consumption amounts to 625,000 st per year (417,000 m3/yr), 62,5% of which is forest wood, 11,7% fruit tree wood, and 25,8% scraps. The resulting pressure on the Moroccan forest is approximately 7,000 ha/year. More than 55% of this consumption is on the part of bath-houses (hammams), 35% on the part of bakeries. The rural fuelwood consumption will be evaluated in a second time, but here and now on can say that moroccan forests are in great danger of disappearance.

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(1) This paper was presented at the XIX IUFRO World Congress, Montreal, Canada. August 1990

INTRODUCTION

In the developing countries, the big majority of the people, and especially the rural population, continue, till today to depend on fuelwood. In many regions, the consumption of fuelwood (principally for cooking and heating) surpasses the potential supply of the forest resour

About 39% of the total energy supply comes from biomass in the developing countries (R. GILLIUSSON, 1984). Of the annual total cutting

of wood in these countries, the cutting of fuelwood accounts for 66%, and the charcoal production for 13%.

Africa, especially south of the Sahara, is one the regions in the Third World where the people dependence on fuelwood in the greastest. Even valuable statisrics are not always available, one could estimate that the proportion of fuelwood in the total energy supply is very high : 60 to 95%, while, in Asia, the rate is relatively low (20 to 50%), and in latin America the situation varyes very widely (15 to 90%).

THE SITUATION IN MOROCCO

Morocco is situated at the North-West part of Africa, at 15km South of Europe. He has an area of 715,000 km2 and a population of about 25 million inhabitants of which more than 57% are rural. Table 1 gives the variation of the moroccan population between 1960 and 1982.

Table 1 : Variation of the moroccan population
(in 1,000 inhab)

year	Urban	Rural	Total	Density inhab. per km2	% of rural population
1960	3,411	8,215	11,626	26.0	70.6
1971	5,410	9,969	15,379	33.5	64.8
1980	8,444	11,606	20,050	28.2(1)	57.8
1982	8,730	11,689	20,719	28.7	57.2

(1) This diminution of density is explained by the recuperation in 1975, of his Sahara by Morocco

The consumption of fuelwood accounts certainly for a high rate of the energy used in MOrocco. Table 2, below, gives the global distribution of energy use in 1984.

Table 2 : Global distribution of energy use (1984)in Morocco

Energy	Consumption (in 1,000 TEP)	% of total
Oil	4,170	61.00
Coal	507	7.42
Hydro-electricity	95	1.39
Natural gas	63	0.93
Fuelwood	2,000	29.26
TOTAL	6,835	100.00

Source : Ministry of Energy and Mimes

As shown in Table 2, about 30% of the total energy supply in Morocco is coming from fuelwood. This rate is the second high one after oil. But the real situation of the consumption of fuelwood in Morocco remains unknown, since no valuable statistics has been made till now. The amount given in Table 2 is only an estimation. Another estimation, to be considered with great reserve, is given in Table 3 and concerns the maroccan fuelwood demand and supply.

Table 3 : Moroccan fuelwood demand and supply (1984)

Demand	:	10,545,014 m3/year
Supply	:	3,341,076 m3/year
Deficit	:	7,162,631 m3/year

OBJECTIVE QUANTIFICATION OF THE CONSUMPTION

Beside the actions of the Ministry of Energy and Mines in the energy domain , the Ministry of Agriculture and Agrairian Reform decided to conduct an objective quantification of fuelwood consumption, on the whole country, urbain and rural parts.

In a first time, we began by the urban consumption taking the big city of Casablanca as an example.

THE CONSUMPTION OF FUELWOOD IN THE CITY OF CASABLANCA

This study was carried out during 1987 and 1988.

Aside from his quantification aim, it has attempted to determine the composition of the consumption as well as the incidence of this latter on Moroccan forests.

The big city of Casablanca has a population of 3 million inhabitants (year 1988). The fuelwood, within it, is principally consumed by :

a) households

b) small enterprises of communal importance : moorish bath -houses (hammams), bread ovens, bakeries, pastry makers, laudries, and dry-cleaners.

c) certain industrial entreprises employing drying rooms for heating wood products : chemical products companies, cork industries,etc.

This latter category of consumers does not utilize wood, strictly speaking; rather it utilizes various scrap materials. We have not considered this category within the scope of this study.

THE SOURCE STUDIED POPULATION

In the territory of the Wilaya of Casablanca, were officially recorded 428 moorish bath-houses (hammams), 1071 ovens/bakeries, and 396 laundries/dry-cleaners.

STATISTICAL METHODOLOGY OF STUDY

The global size of the source population being relatively high (1895 establishments), we have opted for a stratification because, when it is judiciously carried out, stratified random sampling yields more precise information about parameters concerning the entire population (P.G. de VRIES, 1986).

Three strata were constituted : Moorish bath-houses, Ovens-Bakeries, and Laudries-Dry-cleaners. Table 4 gives the different samples drawn

from these different strata.

Table 4 : Distribution of the drawn samples by stratum

	Number of existing establishements (P)	Size of drawn sample (N)	N/P
Moorish bath-houses	428	245	57.2 %
Ovens-Bakeries	1,071	515	48.1 %
Laudries-Dry-cleaners	396	200	20.5 %
TOtal	1,895	960	50.8 %

OBTAINED RESULTS

HOUSEHOLDS CONSUMPTION

The households consumption for both fuelwood and charcoal, within the Wilaya of Casablanca, amounts to approximately 125,000 Q of wood, or about 31,000 st/yr, or about 0.011 st/inh./yr, or 0.06 st/household/yr Table 5 gives the distribution of this consumption between wood and charcoal.

Table 5 : Fuelwood and charcoal consumption of the households within the Wilaya of Casablanca

	Quantity consumed	Equivalent volume of wood
Fuelwood	42,000 Q/yr	10,500 st/yr
Charcoal	83,000 Q/yr	20,750 st/yr
Total	125,000 Q/yr	31,250 st/yr

The conversion norms we have adopted are as follows :

1 m3 of wood = 1.5 steres of wood (st)
1 st of wood = 4 Q of charcoal
1 Q of wood = 60 kg of charcoal

MOORISH BATH-HOUSES CONSUMPTION

More than 98% of Moorish bath-houses in Casablanca utilize wood as their source of energy. The 428 hammams located in Casablanca consume altogether, on the average, 1,344,700Q of wood, or the equivalent of a volume of approximately 336,000 st/yr. This consumption is given with an error equal to 6.4% on 95% - level

The make-up of this consumption of moorish bath-houses is given in Table 6, below.

Table 6 : Composition of the moorish bath-houses consumption the Wilaya of Casablanca

Constituents	% of total consumption
Eucalyptus	42.6
Oak (Quercus sp)	2.8
Pine (Pinus sp)	1.7
Acacia	0.5
Oleaster (olea oleaster)	1.5
Olive (olea europea)	7.4
Almond (Amygdalus)	9.1
Orher wood (Ficus, citrus, etc	4.3
Wood scraps (sawdust, bark)	27.8
Other scraps	2.3

As shown in Table 6, wood, originating in the forest, forms about 49.1 % - nearly half - of the total consumption of moorish bath-houses. Considering the three million inhabitants of the Wilaya of Casablanca, the existing 428 hammams represent an average of approximately :

One moorish bath-house per 7,000 inhabitants.

The global consumption represents a potential pressure on the Maroccan forest of 3,700 ha/yr, and a real pressure of 1,800ha/yr.

Each hammam consumes, annually, on the average, a volume of wood equivalent to an area forested with full- grown trees of :

8,7 ha, as regards the potential consumption

and 4,3 ha, as regards the real consumption

CONSUMPTION OF OVENS-BAKERIES

This consumption amounts to a total of 845,000 Q of wood or the equivalent of 211,000 steres per year. It is given with an error of 4,7% on the 95% - level qignificance.

CONSUMPTION OF LAUDRIES - DRY-CLEANERS

With a relative error of 5,5% on the 95% - level significance, the average consumption of laudries/ dry -cleaners amounts to 130,000Q/yr, or the equivalent of 32,500 steres of wood per year

Finally, the global consumption for the three strata (Moorish bath-houses, Ovens-Bakeries, and laudries - Dry - cleaners) together amounts to nearly 2,320,000 Q, or the equivalent of 580,000 st of wood/yr, with an error of 4% on the 95%- level.

If we add to that the consumption of households (wood + charcoal), we obtain a total consumption in the city of Casablanca of around 2,500,000 Q of wood, or the equivalent of nearly 625,000 steres of wood per year .

Consumption of households	: 125,000 Q	(31,250 st)
Consumption of moorish bath-houses	:1,344,700 Q	(336,000 st)
Consumption of ovens -bakeries	: 845,000 Q	(211,000 st)
Consumption of laudries/dry-cleaners	: 130,000 Q	(32,500 st)
Total	: 2,444,700 Q	
Rounded off to	: 2,500,000 Q	(625,000 st)

The households in the city of Casablanca consume 5.1% of the total fuelwood consumption, the moorish bath houses 55.1%, the ovens-Bakeries 34.6% and the laudries, Dry-cleaners 5.2%.

The fuelwood consumption of Casablanca derives for :

62.5 % from the forest (wood)
11.7 % from fruit tree wood and other non forest wood and
25.8 % from scraps and other waste .

100.0 %

PRESSURE OF FUELWOOD CONSUMPTION ON THE FOREST

In order to translate this pressure on the forest into units of forested hectares consumed, we have taken as our point of reference an afforestation of Eucalyptus camaldulensis of the Gharb (North-Central part of Morocco), aged 10 years and having an average annual growth of 6m3/ha/yr.

In addition, we have distinguished between two types of pressure on forested areas :

- a potential pressure which corresponds to the total consumption of the fuelwood whatever its origin. This pressure is exercised potentially on the forest; it is only partially supported by areas other than forest because of current economic cirumustances (1) .
- a real pressure wich corresponds to the actual (real) levies (of wood) wich are currently drawn from the forest .

POTENTIAL PRESSURE

The potential consumption of 625,000 st/yr translates into a potential pressure equal to :

625,000/ (1.5 * 6 * 10) = 6,944 ha, rounded off to 7,000 ha/yr

The wilaya of Casablanca thus consumes, potentially each year, the equivalent of 7,000 ha of adult forest, to satisfy the fuelwood demand of its inhabitants.

REAL PRESSURE

This pressure corresponds to the volume proper originating in the forest. This volume represents 62,5 % of the total consumption, or around 390,000 st/yr, in other words, the equivalent of 4,300 of adult forest per year .

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(1) The rate of the 11.7% of the total consumption which up of fruit tree wood, appears to be important. In fact, this percentage is inflated due to the consecutive years of drought wich Morocco has experienced recently. In reality, a major part of this percentage is satisfied by the forest.

CONSEQUENCES ON THE NATIONAL SCALE

From this local study, one can consider with a good precision that the rate of fuelwood consumption of moroccantown-dwellers is, at least, equal to 0.208 st/inh./yr, or 0.12 m3/inh. /yr. This gives a global consumptión of town-dwellers equal to :

0.12 * 10.7 million = 1,300,000 m3/yr

Concering the rural consumption of fuelwood, we ignore everything

about it till now. In a second period of this study, we will determine it precisely.

F.A.O. estimates this consumption with a great variation according to many parameters : 0,5 to 2m3 per person and year. If we retain for the moment an average figure of 1 m3/person/year, the moroccan rural consumption of fuelwood would amount to approximately 14,300,000 m3/yr

urbain consumption of fuelwood	: 1,300,00 m3/year
rural consumption of fuelwood	:14,300,00 m3/year
Total	15,600,00 m3/year

This result exceeds that given in Table 3, and aggravates the moroccan deficit of this kind of energy.

CONCLUSION

The consumption of fuelwood largely surpasses the potential supply of the moroccan forests. The country is then facing a great problem for fuelwood energy,more serious than that he is facing with imported oil.

When one knows that beside the problem of fuelwood consumption there are also overgrazing, erosion, in addition to desertification , with on the other hand relatively too few successful efforts of reforestation, one would conclude that the country is loosing its forests.

Unless urgent and appropriate measures are undertaken, what remains of the moroccan forest will disappear within a few decades (M. ELLATIFI, 1982)

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PROBLEMES ENTOMOLOGIQUES DES CEDRES (GENRE *CEDRUS*) EN FRANCE ET EN EUROPE

Jean-Pierre Fabre, Guy Demolin et Paul Du Merle

Institut National de la Recherche Agronomique
Station de Zoologie Forestière
Avenue A. Vivaldi, F-84000 Avignon, France

FDC: 174.7 Cedrus spp.: 453: 145.7 Lepidoptera: 145.7 Homoptera: 145.7 Hymenoptera: (4)

RESUME

Le cortège des insectes déprédateurs des cèdres en Europe se compose actuellement de six espèces. Deux (*Thaumetopoea pityocampa* Denis et Schiff., *Choristoneura murinana* Hb.) sont indigènes sur ce continent, les quatre autres (*Cedrobium laportei* Rem., *Cinara cedri* Mim., *Epinotia cedricida* Diak., *Megastigmus suspectus* var. *pinsapinis* Hoffm.) sont originaires ou très vraisemblablement originaires des cédraies naturelles d'Afrique du Nord. Par ailleurs, plusieurs insectes défoliateurs nuisibles au cèdre en Algérie ou au Maroc (*Dichelia* sp. nov., *Lozotaenia* sp. nov., *Epinotia* sp. nov., *Acleris undulana* Wals., *Thaumetopoea bonjeani* Powell) constituent une menace pour les cédraies ouest-européennes. L'article passe en revue ces différentes espèces.

Mots clés : *Cedrus*, Lépidoptères, Homoptères, Hyménoptères, insectes ravageurs.

SUMMARY

Insect species noxious to cedars (*Cedrus* spp.) in Europe are at present six in number. Two of them (*Thaumetopoea pityocampa* Denis et Schiff., *Choristoneura murinana* Hb.) are indigenous in Europe while the other four (*Cedrobium laportei* Rem., *Cinara cedri* Mim., *Epinotia cedricida* Diak., *Megastigmus suspectus* var. *pinsapinis* Hoffm.) are native to, or in all probability native to, the natural cedar stands of North Africa. On the other hand, several defoliating insects noxious to *Cedrus atlantica* in Algeria or in Morocco (*Dichelia* sp. nov., *Lozotaenia* sp. nov., *Epinotia* sp. nov., *Acleris undulana* Wals., *Thaumetopoea bonjeani* Powell) constitute a threat for the West European cedar stands. A review is given of these different species.

Key words : *Cedrus*, Lepidoptera, Homoptera, Hymenoptera, insect pests.

INTRODUCTION

Le genre *Cedrus* Trew, dont l'aire naturelle est tout entière extérieure à l'Europe, comprend quatre espèces : le cèdre de l'Atlas (*C. atlantica* Manetti - Maroc, Algérie), le cèdre de Chypre (*C. brevifolia* (Hook) Henry - île de Chypre), le cèdre du Liban (*C. libani* (G. Don.) Loud. - Liban, Syrie, Turquie), le cèdre de l'Himalaya (*C. deodara* Loud. - ouest de l'Himalaya). Toutes quatre ont été introduites en Europe, mais le cèdre de l'Atlas est actuellement la seule a y être assez largement utilisée en forêt, principalement en France, où son introduction remonte au milieu du siècle dernier (cédraies du Luberon et du Mont-Ventoux, dans le Vaucluse, du Rialsesse, dans l'Aude). L'importance économique croissante de cette essence en France explique qu'on y porte une attention toute particulière aux problèmes entomologiques des cèdres en général et aux risques d'introduction de nouveaux insectes nuisibles, rendus particulièrement importants par la proximité géographique de l'aire naturelle de ces conifères (Fabre 1976 a).

A l'heure actuelle, l'entomofaune phytophage signalée sur cèdre, et plus particulièrement sur cèdre de l'Atlas, en Europe se compose de six espèces : la processionnaire du pin, *Thaumetopoea pityocampa* Denis et Schiff. (Lep. Thaumetopoeidae), les tordeuses *Epinotia cedricida* Diak. et *Choristoneura murinana* Hb. (Lep. Tortricidae), les pucerons *Cedrobium laportei* Rem. et *Cinara cedri* Mim. (Hom. Lachnidae), le chalcidien séminivore *Megastigmus suspectus* Borr. var. *pinsapinis* Hoffm. (Hym. Torymidae). La processionnaire du pin, dont l'aire naturelle s'étend des deux côtés de la Méditerranée, comptait déjà, au sud de celle-ci, des cèdres au nombre de ses hôtes naturels ; les deux pucerons sont originaires d'Afrique du Nord, de même, très vraisemblablement, qu'*Epinotia cedricida* et que les populations de *Megastigmus suspectus* observées sur cèdre en France ; *Choristoneura murinana* est en revanche un insecte européen s'étant porté secondairement sur le cèdre.

Les dates et lieux de première observation sur cèdre, en Europe, de ces insectes - la processionnaire du pin étant évidemment exclue - sont les suivantes (l'essence concernée est dans tous les cas le cèdre de l'Atlas) : 1950 (ou peu avant), *Megastigmus suspectus* var. *pinsapinis*, en France (Berland 1950) ; - 1967, *Cedrobium laportei*, en France (Emmonot *et al.* 1967) ; - 1968, *Epinotia cedricida*, en France (Diakonoff 1969 ; Leclant & Remaudière 1969) ; - 1973, *Cinara cedri*, en Italie (Covassi & Binazzi 1974) ; - 1982, *Choristoneura murinana*, en France (Fabre *et al.* 1987 ; Du Merle *et al.* 1989). Bien que ces dates soient sans nul doute bien postérieures à celles de l'apparition en Europe des insectes en question sur le cèdre, leur énumération et leur comparaison avec celle du début de l'utilisation forestière de l'essence sur ce continent (vers 1860) illustrent parfaitement le caractère lent et progressif de la colonisation des essences introduites par des cortèges d'insectes phytophages.

L'étude des six espèces précitées constitue depuis longtemps un des principaux thèmes de recherche de la Station de Zoologie Forestière d'Avignon. Les observations correspondantes sont effectuées principalement en région méditerranéenne française. De nombreuses missions exploratoires puis de travail en Algérie et au Maroc ont d'autre part permis d'acquérir, en collaboration avec les entomologistes forestiers de ces pays, des informations sur le complexe - jusqu'alors largement inconnu - des insectes

nuisibles au cèdre de l'Atlas dans son aire naturelle, notamment sur plusieurs espèces défoliatrices non encore signalées en Europe mais menaçant tout particulièrement celle-ci : processionnaire du cèdre (*Thaumetopea bonjeani* Powell, Lep. Thaumetopoeidae) et diverses tordeuses (Lep. Tortricidae).

On passera brièvement en revue ces différents ravageurs, en distinguant successivement les espèces indigènes en Europe, les espèces européennes originaires de l'aire naturelle du genre *Cedrus*, enfin les espèces défoliatrices non encore signalées au nord de la Méditerranée.

ESPECES INDIGENES EN EUROPE

La processionnaire du pin, *Thaumetopoea pityocampa*

Principal insecte défoliateur des pins dans les pays du pourtour méditerranéen, et ayant donné lieu, à ce titre, à une abondante littérature entomologique forestière, cette processionnaire compte également le cèdre au nombre de ses hôtes naturels. En France, ses dégâts sur cèdre de l'Atlas sont presque toujours minimes. Les boisements de cèdre y sont en effet généralement situés un peu en marge de l'aire bioclimatique optimale de l'insecte (Demolin 1969 b ; Huchon & Demolin 1970) tout en se trouvant le plus souvent peu éloignés de peuplements de pins, essences convenant beaucoup mieux aux femelles pour le dépôt des oeufs (Demolin 1969 a). On reviendra sur cette processionnaire dans le chapitre traitant de *Thaumetopoea bonjeani*.

La tordeuse du sapin, *Choristoneura murinana*

Au printemps 1987, une pullulation d'une nouvelle tordeuse nuisible au cèdre de l'Atlas fut découverte dans la cédraie du Luberon (Vaucluse) vers 700 m d'altitude (Fabre *et al.* 1987). Des chenilles du même insecte avaient déjà été observées, en petit nombre, dans ce peuplement en 1982. La tordeuse paraissait appartenir à l'espèce européenne *Choristoneura murinana*, dont les hôtes connus se limitaient jusqu'alors au sapin pectiné, *Abies alba* Mill., et, dans le sud de la Grèce, au sapin de Céphalonie, *A. cephalonica* Loud. C'est ce que confirmèrent l'examen des pièces de l'armature génitale des adultes mâles, la réponse de ces derniers à la phéromone sexuelle de synthèse de *Choristoneura murinana*, enfin et surtout les résultats de croisements réciproques entre le nouveau ravageur et des *Choristoneura murinana* vivant sur sapin (Du Merle *et al.* 1989).

Depuis, la présence de la tordeuse a été mise en évidence dans dix autres cédraies du sud-est de la France, toutes situées, de même que celle du Luberon, dans des milieux plus chauds et secs que ceux convenant au sapin (Du Merle & Cornic 1989 ; Du Merle *et al.* 1989). Ces faits joints à d'autres données relatives à la distribution actuelle connue de l'insecte prouvent que celui-ci est capable de coloniser avec succès des milieux très variés,

pouvant différer profondément de son habitat d'origine, l'aire naturelle du sapin. En France, où celle-ci se limite pour l'essentiel à certaines portions de l'étage de végétation montagnard, la tordeuse est en fait vraisemblablement apte à se développer un peu partout depuis le littoral (Manche, Atlantique, Méditerranée) jusqu'aux abords de l'étage subalpin (Du Merle & Cornic 1989), donc, en particulier, dans tous les milieux susceptibles d'être boisés en cèdre.

Le fait que *Choristoneura murinana*, naturellement monophage sur *Abies*, puisse se développer et même pulluler sur cèdre est moins étonnant qu'il n'y paraît au premier abord. On sait en effet, d'une part que le genre *Cedrus* a existé en Europe jusqu'au pléistocène et, d'autre part, que ce genre est, de tous les genres d'Abietoideae, le plus proche au plan phylogénétique du genre *Abies*. Il se pourrait dès lors que la tordeuse ait déjà compté autrefois des cèdres au nombre de ses plantes hôtes. Le sapin pectiné, quant à lui, doit sans doute être considéré aujourd'hui comme un réservoir d'espèces susceptibles, pour certaines, de passer sur cèdre et de s'y montrer nuisibles (Du Merle *et al.* 1989).

ESPECES ORIGINAIRES DE L'AIRE NATURELLE DU CEDRE

Les pucerons *Cedrobium laportei* et *Cinara cedri*

Les deux espèces sont monophages sur cèdre. *Cedrobium laportei* a été décrit en 1954 par Remaudière à partir d'individus récoltés au Maroc et aux environs d'Alger sur cèdre de l'Atlas. Au cours de nos missions en Algérie, sa présence a été constatée dans toutes les cédraies prospectées, notamment en Grande et Petite Kabylie, dans les Aurès, dans le Hodna, dans les cédraies de Chréa, au sud de Blida, et de Baienem, à l'ouest d'Alger (Fabre, missions 1987, 1988, 1989). *Cinara cedri* a été décrit du Maroc, sur cèdre de l'Atlas, par Mimeur (1935). Depuis, il a été découvert en Algérie (Fabre, mêmes missions ; l'insecte a été observé dans toutes les cédraies prospectées sauf une), mais aussi en Turquie (Tuatay & Remaudière 1964) et au Liban (cédraie de Barouk, J. Riom non publié, 1980) sur cèdre du Liban.

En Europe, *Cedrobium laportei* a été signalé en Espagne, Italie, France, Angleterre et aux Pays-Bas, *Cinara cedri* en Espagne, Italie et France (Fabre 1988 ; la découverte de l'espèce en France date de 1974 : Fabre 1976 b).

La biologie et la dynamique des populations des deux pucerons ont fait l'objet, dans le sud-est de la France, d'observations pendant une dizaine d'années (Fabre non publié). *Cinara cedri* a, dans ce pays, un cycle complet, avec apparition à l'automne de sexupares puis de sexués, suivie du dépôt d'oeufs d'hiver. En revanche, *Cedrobium laportei* ne s'y reproduit que par voie parthénogénétique, à partir de femelles virginipares aptères ou ailées. En région méditerranéenne française, les niveaux de population des deux pucerons se montrent très variables d'une année et d'un site à l'autre. Le principal facteur limitant pour *Cedrobium laportei* est sans aucun doute la température. Des pullulations de l'insecte ne sont en effet observées qu'à basse altitude, dans l'étage de végétation mésoméditerranéen et - à un degré

moindre - dans le bas du supraméditerranéen, autrement dit dans des milieux correspondant approximativement à l'étage du chêne vert (*Quercus ilex* L.). Elles peuvent y être très sévères, provoquant alors une forte défoliation des arbres, voire la mort d'un certain nombre de ceux-ci (Fabre 1982, 1988). Aux altitudes plus élevées, dans le supraméditerranéen, le puceron est présent mais apparemment toujours à bas niveau de population. Des pullulations spectaculaires de *Cinara cedri* s'observent parfois également dans l'étage du chêne vert. A la différence de l'espèce précédente, ce puceron, même lorsqu'il pullule, parait toutefois n'être que peu nuisible aux arbres.

La susceptibilité comparée des quatre espèces de cèdres à chacun des deux pucerons à été étudiée dans des plantations comparatives du sud-est de la France (Fabre 1988). *Cinara cedri* peut infester avec succès les quatre espèces de cèdres. En revanche, *Cedrobium laportei* apparaît beaucoup plus spécifique : le cèdre de l'Atlas est de loin celui convenant le mieux à son développement ; le puceron n'infeste pas spontanément les cèdres de Chypre et du Liban et, en cas d'infestation artificielle, ne réussit à se maintenir que brièvement sur ces essences ; le cèdre de l'Himalaya paraît occuper une position intermédiaire.

Au printemps 1981, le parasite *Pauesia cedrobii* Stary et Leclant (Hym. Aphidiidae), spécifique de *Cedrobium laportei*, a été introduit, à partir du Maroc, dans un des boisements de cèdres du Luberon (Vaucluse). Par la suite, l'expérience a été étendue aux principaux peuplements de cèdre du sud-est de la France (Fabre & Rabasse 1987). Le parasite s'est bien acclimaté dans les lieux d'introduction tout en faisant preuve de capacités de dispersion importantes. Son introduction au nord de la Méditerranée a donc été une réussite. Les observations faites au Luberon suggèrent que son efficacité dans la régulation des populations du puceron serait importante, mais on ne peut encore être affirmatif à cet égard tant il est difficile de l'évaluer objectivement.

Une introduction généralisée du parasite en France, voire dans le reste de l'aire du cèdre en Europe, nécessiterait de disposer d'élevages permanents de l'insecte. Afin de définir les conditions optimales pour de tels élevages, neuf conditions climatiques ont été testées en chambres climatisées, chacune pendant un an et demi, en utilisant comme support d'élevage des cèdres de l'Atlas âgés d'environ 6-7 ans, cultivés en pots et infestés artificiellement par des colonies de *Cedrobium laportei*. C'est à la température de 12°C que les meilleurs résultats ont été obtenus (Fabre 1989 a). Ces essais permettent de poser les bases d'un élevage de masse du parasite. L'introduction de celui-ci en forêt pourrait s'effectuer selon deux voies : soit par transport sur place de plants de cèdres provenant de l'élevage, soit, dans le cas des parcelles trop éloignées, en prélevant dans l'élevage des momies du puceron puis en les faisant éclore directement sur les lieux d'introduction.

La tordeuse *Epinotia cedricida*

Cette tordeuse a pour seul hôte connu le cèdre de l'Atlas. Initialement décrite sur des individus récoltés en France dans la cédraie du Luberon (Diakonoff 1969), elle a été découverte depuis au Maroc (Fabre 1976 a ; Leclant *et al.* 1977) puis en Algérie (Cavalcaselle 1985). Bien que

l'appartenance à l'espèce *cedricida* des insectes observés au Maroc soit un peu incertaine, il y a donc tout lieu de penser que l'insecte est originaire d'Afrique du Nord.

En Europe, la tordeuse n'a, à ce jour, été signalée qu'en France. La dynamique de ses populations y est suivie dans une trentaine de sites répartis dans le sud du pays, le niveau de population de l'insecte étant estimé à partir du taux d'attaque des bouquets d'aiguilles (Fabre non publié). A l'inverse du puceron *Cedrobium laportei*, la tordeuse ne commet des dégâts important qu'à des altitudes relativement élevées, correspondant approximativement à l'étage de végétation supraméditerranéen donc à l'optimum bioclimatique du cèdre en région méditerranéenne française. Les gradations de l'insecte revêtent un caractère plus ou moins cyclique, les pullulations s'observant tous les 5-6 ans environ. Les parasites ne jouent, semble-t-il, qu'un rôle tout à fait négligeable, à l'inverse des entomopathogènes (mycoses), dont l'action, peut-être liée à celle de facteurs trophiques, paraît être prépondérante dans la régulation des populations.

Le chalcidien séminivore *Megastigmus suspectus* var. *pinsapinis*

La position taxonomique de ce parasite des graines, et par suite son origine géographique, ne sont pas encore très claires. Il semble bien que la forme *pinsapinis* soit en fait une espèce distincte de *suspectus* et que, d'autre part, ses populations observées sur cèdre en France soient originaires d'Afrique du Nord (Pintureau *et al.* en préparation). Cette forme y a été signalée par Milliron en 1949. Depuis, elle a été retrouvée au Maroc, dans le Rif, et en Algérie (missions Fabre 1980, 1987).

La formation et le développement des cônes du cèdre de l'Atlas s'échelonnent sur 3 ans. Leur infestation par l'insecte se produit au printemps de l'année N + 1 (cônelets de couleur vert tendre, à teneur en eau très élevée). Les larves parviennent à maturité à l'automne et entrent alors en diapause. La majorité d'entre elles passent les deux hivers suivants dans cet état et se nymphosent au printemps de l'année N + 4 ; certaines restent toutefois en diapause prolongée une année de plus (Fabre 1986).

Une étude de la répartition spatiale de l'insecte à l'intérieur des arbres a montré que le taux d'infestation des graines est peu sensible à l'orientation des cônes sur l'arbre mais croît assez fortement du bas vers le haut des houppiers. D'un autre côté, le taux de graines avortées tend à être maximal à la fois sur les plus basses branches et en cime. C'est donc dans la partie médiane des houppiers que doivent être de préférence effectuées les récoltes de cônes destinées à l'obtention de semences (Fabre 1989 b).

Les fluctuations des populations du parasite se montrent très liées à celles de la production de cônes par les arbres, elle-même très variable selon l'année : le taux de parasitisme des graines varie en sens inverse de l'effectif des cônes l'année de l'attaque, selon une relation de type $y = a \text{ Log } x + b$, ce qui permet de le prévoir une année et demie avant la récolte. L'existence d'une diapause prolongée touchant une certaine fraction de la population est bénéfique à deux titres pour l'insecte : elle évite que

l'ensemble des individus n'émergent une année où les cônes de 1 an seraient très peu abondants et permet, d'autre part, des échanges génétiques entre les populations issues respectivement des cônes infestés les années paires et impaires (Fabre 1986).

ESPECES DEFOLIATRICES D'AFRIQUE DU NORD NON ENCORE PARVENUES EN EUROPE

Les tordeuses (Lep., Tortricidae)

Trois espèces de tordeuses défoliatrices du cèdre de l'Atlas, nouvelles pour la science et en cours de description, viennent d'être découvertes en Algérie (missions Fabre 1987, 1988). Elles appartiennent respectivement aux genres *Dichelia* Guenée (syn. *Parasyndemis* Obr.), *Lozotaenia* Steph. et *Epinotia* Hb. La première parait assez voisine de *Dichelia cedricola* décrit du Liban, sur *Cedrus libani*, par Diakonoff (1974) et dont la biologie a été étudiée par Baloch & Kawar (1978). Elle attaque non seulement le cèdre de l'Atlas mais aussi, et surtout, le sapin de Numidie (*Abies numidica* de Lannoy), dont l'aire naturelle se limite au massif des Babors (Algérie). Il existe donc un risque, si elle parvient un jour en Europe, qu'elle s'y montre nuisible tant aux sapins qu'aux cèdres.

En 1980, une nouvelle espèce pour le Maroc de tordeuses nuisibles au cèdre a été découverte dans le Moyen Atlas : *Acleris* (syn. *Acalla*) *undulana* Wals. (Fabre & Mouna 1983). Cette tordeuse était connue de Turquie, Syrie et de l'île de Chypre (Razowski 1966). En Turquie, ses ravages sur cèdre du Liban concernent certaines années des surfaces considérables (60 000 ha en 1969) (Ekici 1970). L'espèce n'a pour le moment été trouvée ni dans le nord du Maroc (cédraies du Rif) ni en Algérie. Sans doute est-elle originaire d'Asie Mineure et n'est-elle parvenue qu'assez récemment dans les cédraies du Moyen Atlas marocain, où elle commet des dégâts importants depuis la fin des années 1970 (Fabre & Mouna 1983 ; Mouna 1988). Sa biologie a été étudiée par Ekici (1970) puis par Mouna (1988).

La processionnaire du cèdre, *Thaumetopoea bonjeani*

Quatre espèces de processionnaires attaquent le cèdre sur le pourtour du Bassin Méditerranéen : *Thaumetopoea pityocampa* Denis et Schiff., *T. wilkinsoni* Tams, *T. bonjeani* Powell et *T. libanotica* Kiriakoff et Talhouk. Les deux premières sont connues sous le nom de "processionnaires du pin" car elles figurent parmi les ravageurs les plus redoutables de ces conifères. *T. pityocampa* est présent au nord et au sud-ouest de la Méditerranée, *T. wilkinsoni* au sud-est de celle-ci. En fait, *T. wilkinsoni* n'est vraisemblablement pas une "bonne espèce" mais seulement la forme orientale de *T. pityocampa* (Demolin 1966, 1969 b, 1988). Les deux autres espèces peuvent être, quant à elles, dénommées "processionnaires du cèdre", car leurs seuls hôtes connus appartiennent au genre *Cedrus*. Elles ont été respectivement signalées : *T. libanotica*, au Liban, d'où cette processionnaire a été récemment décrite par Kiriakoff & Talhouk (1975) sur cèdre du Liban, *T.*

bonjeani, en Afrique du Nord, où l'espèce, décrite du Moyen Atlas marocain par Powell (1922), vit sur cèdre de l'Atlas.

La présence sur cèdre de ce complexe d'espèces a été à l'origine de nombreuses confusions. On a ainsi longtemps attribué à *T. bonjeani* tous les dégâts de processionnaire constatés dans les cédraies marocaines. En réalité, les observations effectuées au cours de multiples missions dans les pays du sud du Bassin Méditerranéen (Demolin 1988 et non publié) et les informations recueillies auprès des gestionnaires forestiers nous conduisent à penser que la plupart des pullulations de processionnaire survenant dans les cédraies de ces pays sont dues à *T. pityocampa-wilkinsoni*, que ce soit sur cèdre du Liban (Turquie, Liban) ou sur cèdre de l'Atlas (Algérie, Maroc ; pour ce dernier pays, voir Questienne & Miermont 1979 ; Cervera *et al*. 1981).

Cette espèce n'est toutefois pas la seule à pouvoir pulluler sur cèdre : une forte infestation de *T. libanotica* s'est déclarée au Liban, dans la cédraie de B'Charré, au début des années 1980 (H. Tohmé comm. pers.), tandis que *T. bonjeani* a commencé à commettre des dégâts importants dans les cédraies du Moyen Atlas marocain en 1983 (El Yousfi 1989). Parallèlement, on observait, en 1982, une explosion démographique de processionnaire dans la cédraie du Belezma, en Algérie, mais il fallut attendre 1984 (mission Demolin en Algérie) pour reconnaître que l'espèce en cause était bien *T. bonjeani*, jusqu'alors non signalé de ce pays.

T. bonjeani doit donc être considéré aujourd'hui comme un ravageur important du cèdre. Sa biologie et son complexe parasitaire ont fait l'objet de plusieurs études (Cervera *et al*. 1981, Gachi *et al*. 1986, Demolin 1988, El Yousfi 1989). La période de développement larvaire chez cet insecte, de même d'ailleurs que chez *T. libanotica*, se situe au printemps et au début de l'été, ce qui fait de ces deux espèces des "processionnaires d'été", par opposition à *T. pityocampa-wilkinsoni* dont le développement larvaire s'étend de la fin de l'été au début du printemps et que l'on peut par suite qualifier de "processionnaire d'hiver".

La phéromone sexuelle de *T. bonjeani* a été récemment identifiée (Frérot *et al*. 1989).

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AMELIORATION GENETIQUE, CROISSANCE ET FRUCTIFICATION DU CEDRE DE L'ATLAS (*Cedrus atlantica* Manetti) EN FRANCE MERIDIONALE

Pierre FERRANDES, Helfried OSWALD, Jean TOTH

Institut National de la Recherche Agronomique
Département des Recherches Forestières
AVIGNON, France

FDC: 174.7 Cedrus atlantica Manetti: 181.52: 165.3: 23: (44)

RESUME

Le Cèdre de l'Atlas a été introduit dans les reboisements en France méridionale à partir de 1862. De nouveau très utilisé depuis les années 1950 en raison de sa relative plasticité vis-à-vis du milieu, de sa régénération naturelle abondante, de sa bonne croissance, de la qualité de son bois et de son faible combustibilité. La superficie potentielle d'introduction est éstimée à plus de 200 000 ha. Avec plus de 1000 ha plantés chaque année, le Cèdre de l'Atlas est actuellement la première essence de reboisement dans la France méridionale. Des peuplements à dominance de Cèdre existent aujourd'hui dans plus de 24 départements et couvrent environ 15 000 ha. La France se trouve ainsi en tête des pays possédant des cédraies en dehors de l'aire naturelle de l'espèce. Les principaux résultats acquis depuis plus de 25 ans par la recherche forestière française dans les domaines de l'amélioration génétique, de la biologie florale et de la sylviculture ainsi que les perspectives de ces recherches sont exposés.

SUMMARY

The Atlas Cedar (*Cedrus atlantica*) has been used for reafforestation in southern France since 1862. Today, pure or mixed stands of this species, covering more than 15 000 ha, can be found in more than 24 "départements" and the evaluated potential area of introduction amounts to more than 200 000 ha. Due to its adaptation to a wide range of site conditions, its natural regeneration facilities, its good growth and wood quality and its relative resistance against fire, the importance of the species is steadily growing since the early 1950's, and more than 1000 ha are actually planted each year. The principal research results obtained during the past 25 years by the French forest research in the fields of genetics, biology of flowering, silviculture and growth and yield, as well as the perspectives are presented.

INTRODUCTION

Le genre Cedrus est représenté par quatre espèces : le Cèdre de l'Atlas (*Cedrus atlantica* Manetti), le Cèdre du Liban (*Cedrus libani* (G. Don.) Loud), le Cèdre de Chypre (*Cedrus brevifolia* (Hook) Henry) et le Cèdre de l'Himalaya (*Cedrus deodara* Loud.).

Le Cèdre de l'Atlas, originaire d'Afrique du Nord (Algérie, Maroc), a été introduit dans les reboisements en France à partir de 1862. Des peuplements à dominance de Cèdre, issus de plantation ou de régénération naturelle, existent aujourd'hui dans plus de 24 départements et couvrent environ 15 000 ha, mais on rencontre des arbres disséminés ou par petits bouquets sur des superficies assez importantes. L'utilisation du Cèdre dans les reboisements a pris un nouvel essor à partir des années 1950 et on en plante actuellement plus de 1 000 ha chaque année. La France se trouve ainsi en tête des pays possédant des cédraies en dehors de l'aire naturelle de l'espèce.

L'aire potentielle d'extension des Cèdres en France méridionale peut être évaluée à plus de 200 000 ha. Elle concerne surtout les étages du Chêne vert (*Quercus ilex* L.), du Chêne pubescent (*Quercus lanuginosa* Lambk.) et du Châtaignier (*Castanea sativa* Miller), entre 250 à 900 m d'altitude. Dans l'arrière-pays (Alpes du Sud, Cévennes, Pyrénées orientales), le Cèdre de l'Atlas peut localement être introduit en versant sud jusqu'à 1200 m d'altitude et éventuellement plus. Dans l'étage mésoméditerranéen inférieur et à basse altitude en général, son introduction doit être limitée à des stations plus fraîches sur versant nord ou à sol profond pour compenser la faible pluviosité et une sécheresse estivale souvent supérieure à deux mois.

Le Cèdre de l'Atlas est réputé assez indifférent vis-à-vis de la roche mère et de la nature du sol, excepté les sols très compacts ou superficiels (marnes, argiles, calcaires non fissurés), où sa croissance est faible. Il craint également l'hydromorphie et les sols à pH supérieur à 8. L'enracinement est puissant, pivotant et profond et de ce fait les chablis dus au vent sont assez rares.

Les aiguilles des Cèdres et la litière très compacte des cédraies sont peu à modérément inflammables. Les peuplements de Cèdres a couvert fermé sont peu combustibles et présentent des risques très faibles d'éclosion et de propagation du feu.

Les Cèdres produisent un bois de qualité, assez homogène et très durable. Ce bois est utilisable en ébénisterie et en menuiserie extérieure et il est apte au déroulage et au tranchage. Les produits d'éclaircie de faible dimension trouvent leurs débouchés dans le coffrage, la palette et la pâte à papier (QUIQUANDON, 1976).

L'essentiel des recherches françaises sur les Cèdres sont menées par les différents laboratoires du Département des Recherches Forestières de l'I.N.R.A. et notamment par la Station de Sylviculture Méditerranéenne et la Station de Zoologie Forestière à Avignon, par le Laboratoire d'Amélioration des Conifères à Bordeaux et de son Domaine Expérimental du RUSCAS à Bormes-les Mimosas (Var), ainsi que par le Laboratoire de Bioclimatologie et d'Ecophysiologie Forestière à Nancy. Il faut également y ajouter la Division "Techniques Forestières Méditerranéennes" du C.E.M.A.G.R.E.F. à Aix-en-Provence et certains laboratoires des universités et du Centre National de la Recherche Scientifique avec lesquels l'I.N.R.A. coopère.

Le "Guide Technique du Forestier Méditerranéen Français" propose en 8 chapitres une synthèse de l'ensemble des connaissances scientifiques et techniques acquises; les chapitres 3 "Essences forestières" et 4 "Protection des forêts contre l'incendie" viennent d'être publiés. (C.E.M.A.G.R.E.F. 1989) et les six chapitres restants le seront au fur et à mesure de leur rédaction.

BIOLOGIE FLORALE ET FRUCTIFICATION

Les études menées entre 1972 et 1988 sur la biologie florale et sur l'estimation quantitative et qualitative de la fructification du Cèdre de l'Atlas (TOTH, 1978) ont permis d'élaborer une méthode de prévision de la fructification, capitale pour l'organisation des récoltes de cônes(TOTH, 1984).

Le cycle de la reproduction

Le Cèdre de l'Atlas (classe des gymnospermes, groupe des conifères) est monoïque, mais on observe souvent des arbres qui ne portent que des fleurs mâles ou que des fleurs femelles. Le Cèdre devient fructifère entre 20 et 30 ans selon les stations. Les inflorescences apparaissent sur des rameaux courts d'âges variés à tous les niveaux de l'arbre, mais environ 80% des cônes se trouvent entre 25% et 75% de la hauteur des houppiers avec un très net minimum (10%) dans la partie exposée au nord.

Les fleurs mâles apparaissent en fin juin de l'année N, sous la forme de bourgeons arrondis de quelques millimètres de diamètre, situés au coeur d'une rosette d'aiguilles et de couleur vert tendre. Leur taille définitive (10 mm de diamètre et 40 à 50 mm de longueur) est atteinte début septembre Devenant jaune verdâtre, elles arrivent à maturité à la mi-septembre, où elles s'ouvrent et disséminent le pollen (pollinisation anémophile). Elles sèchent ensuite assez rapidement et tombent pendant l'automne et l'hiver.

L'inflorescence femelle, qui au début est très semblable à la fleur mâle, commence son développement seulement fin aoûtde l'année N. Elle croît rapidement jusqu'à mi-septembre, et atteint environ 5 mm de diamètre et 15 mm de longueur, taille inférieure à celle des fleurs mâles à la même époque, tout en restant bien verte. Ses écailles s'entrouvrant alors, ce qui la rend réceptive au pollen apporté par le vent.

En octobre, les écailles se referment lentement L'inflorescence femelle devient "cônelet" et passe l'hiver sans changer de dimensions ou de couleur. Pendant les deux mois qui suivent le débourrement des bourgeons végétatifs, c.à.d. de fin mars à fin mai de l'année N+1, les cônelets et leurs ovules doublent approximativement leurs dimensions. Pendant toute cette période on observe fréquemment des avortements de cônelets.

Fin mai, les grains de pollen émettent leurs tubes polliniques vers l'intérieur de l'ovule, permettant ainsi la fusion des gamètes mâles et femelles, c'est-à-dire la fécondation. Les cônelets deviennent alors des cônes qui, tout en gardant leur couleur verte, vont continuer à grossir jusqu'en septembre, époque où ils atteignent leur taille définitive (30 à 50 mm de diamètre et 50 à 80 mm de longueur). En octobre, leur couleur vire au violet puis au marron-roux, par oxydation de la résine suintante, et leur poids commence à diminuer par déshydratation. A la fin de l'année N+1, les cônes ne contiennent plus que 20 % d'eau. A ce stade, les graines sont déjà formées et possèdent bien distinctement embryon, endosperme et tégument.

La déshydratation des cônes, qui ne changent pas d'aspect, se poursuit lentement jusqu'à fin août de l'année N+2. En septembre les écailles commencent à s'ouvrir. Courant octobre, dans des conditions climatiques "normales", les écailles sont complètement ouvertes.

La désarticulation des cônes et la dissémination des graines commencent vers la mi-novembre de l'année N+2 et peuvent durer, si l'hiver est doux, jusqu'en avril de l'année N+3. Trois conditions doivent être réunies pour provoquer la désarticulation des cônes : une absorption d'eau ou "imbibition" doit être suivie d'un gel tissulaire, puis d'un dégel. C'est seulement dans ces conditions, qui ne sont pas toujours réunies à basse altitude, que les cônes peuvent se désarticuler et libérer d'eux-mêmes les graines. Les rachis des cônes peuvent demeurer plusieurs années sur les rameaux. Les graines sont ailées et disséminées par le vent, mais les eaux de ruissellement et les animaux (rongeurs, oiseaux) contribuent également à la dispersion des graines tombées au sol.

Importance et périodicité des fructifications

La Station de Sylviculture Méditerranéenne de l'I.N.R.A. a suivi de 1973 à 1988 l'évolution qualitative et quantitative de la fructification dans plusieurs peuplements ou groupes d'arbres, répartis dans quelques grands massifs: Mont-Ventoux et Lubéron (Vaucluse), Rialsesse et Marcilly (Aude), et représentant des stations écologiques diverses et des années aux conditions climatiques très variées.

Les premiers résultats montrent une périodicité de la fructification de l'ordre de 3 à 5 années. La figure 1, relative à une plantation d'une cinquantaine d'années sur le versant sud du Mont Ventoux (700 m d'altitude) en fournit un exemple. On remarquera la fructification exceptionnelle de 1982, estimée à environ 200 kg de graines viables à l'hectare; ceci ne correspond évidement pas à la possibilité de récolte.

Dans les massifs provencaux calcaires du Ventoux (exposition sud, 800 m d'altitude) et du Lubéron (plateau sommital, 700 m d'altitude) les fructifications sont généralement d'une meilleure qualité (proportion de graines saines et taux de germination plus élevés) que dans le massif cristallin du Rialsesse (exposition nord, 700 m d'altitude), où on trouve cependant la plus forte croissance du Cèdre; le massif de Marcilly, également sur roche mère cristalline (exposition sud-ouest, 400 m d'altitude), occupe une position intermédiaire.

Le long cycle de développement (26 mois au minimum, entre la pollinisation et la dissémination des graines mûres), offre de larges possibilités de prévision quantitative et qualitative de la fructification. Une première estimation, quoique peu précise, est déjà possible à partir de l'abondance de la floraison femelle, en octobre de l'année N (26 mois à l'avance), ou à partir de celle des cônelets fécondés en mai de l'année N+1 (18 mois à l'avance). Une estimation plus précise peut être obtenue en août ou en septembre de l'année N+1 (13 à 14 mois avant la récolte) par un comptage des cônes verts de un an sur des arbres-échantillons.

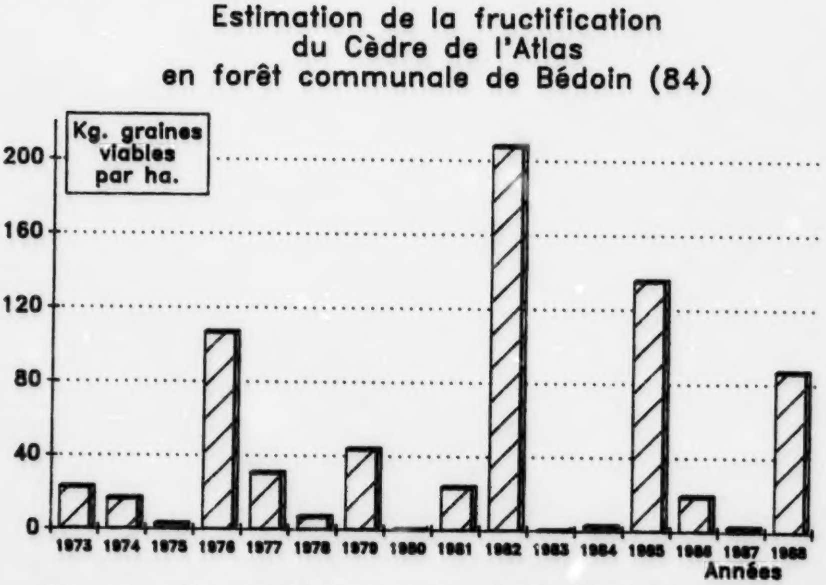


Figure 1 : Périodicité de la fructification de 1973 à 1988.

Pour faciliter l'organisation de la récolte de graines, il peut être utile de connaître avec une assez bonne précision la proportion de graines saines. Ceci peut se faire facilement quelques mois avant la récolte par prélèvement d'un échantillon de cônes, à prendre au milieu des houppiers. La détermination de la proportion de graines saines peut se faire par radiographie ou par tri densimétrique dans de l'alcool à 99% (FABRE, 1986, 1989).

La désarticulation des cônes récoltés se fait par trempage dans l'eau pendant plusieurs jours. Les graines à l'état sec (taux d'humidité inférieur à 10%) peuvent être stockées pendant plusieurs années en chambre froide (température inférieure à + 4° C) dans des conteneurs hermétiquement clos sans perte notable de leur pouvoir germinatif. Après stockage et avant semis les graines doivent subir un traitement de levée de la dormance. Les graines sont trempées dans l'eau pendant 3 heures puis stratifiées entre -2 et +4°C dans du sable humide pendant 2 à 6 semaines. Le taux de germination est de l'ordre de 60 à 90% .

En ce qui concerne la récolte de graines, trois régions de provenances ont été retenues en France et 49 peuplements, couvrant 1 364 ha, ont été classés conformément aux réglementations en vigueur dans la CEE. Dans ces peuplements l'essentiel de la récolte des graines est assuré par l'Office National des Forêts, qui les traite et les stocke dans sa sécherie de La Joux et qui les commercialise.

Quelques renseignements sur les fructifications, la récolte des cônes et sur les graines du Cèdre de l'Atlas sont donnés ci-après :

Epoque de récolte	: septembre et octobre de l'année N+2
Nombre moyen d'arbres récoltables à l'ha :	
- fructification moyenne	20
- fructification forte	40
Volume de cônes par arbre récoltable :	
- fructification moyenne	0,2 à 0,5 hl
- fructification forte	0,3 à 0,8 hl
Volume de cônes récoltable à l'ha :	
- fructification moyenne	4 à 10 hl
- fructification forte	12 à 32 hl
Rendement en graines d'un hl de cônes	3 à 4 kg
Rendement en graines d'un ha :	
- fructification moyenne	12 à 40 kg
- fructification forte	35 à 130 kg
Rendement de la main-d'oeuvre :	
- par grimpage (fructification moyenne)	1 à 4 hl/homme/jour
- par grimpage (fructification forte)	4 à 8 hl /homme/jour
- sur arbres abattus	8 à 12 hl/homme/jour

Nombre de cônes par hectolitre	400 à 500
Poids d'un hectolitre de cônes frais	30 à 40 kg
Nombre de graines par cône	120 à 140
Poids de 1000 graines	65 à 85 g
Nombre de graines/kg	12000 à 15000
Faculté germinative (après traitement de levée de dormance)	60 à 80 %

AMELIORATION GENETIQUE ET SELECTION

Objectifs et critères de sélection.

L'objectif est de sélectionner au sein du genre Cedrus un matériel végétal apte à être utilisé pour la reconstitution de la forêt méditerranéenne par la création de peuplements productifs, se régénérant naturellement, adaptés aux sols carbonatés, et peu combustibles. L'objectif à plus long terme consiste en la création de matériel végétal nouveau par hybridation, alliant les performances en croissance de C. atlantica et la résistance à la sécheresse de C. libani.

Les principaux critères évalués sont les suivants :

- Adaptation : Sécheresse, froid hivernal, sols carbonatés.
- Croissance : Hauteur, diamètre, volume (forte croissance juvénile).
- Branchaison : Angle d'insertion,nombre, grosseur (fermeture rapide du couvert souhaitée).
- Sensibilité aux pucerons : *Cedrobium laportei, Cinaria cedri.*
- Sensibilité à une tordeuse : *Epinotia cedricida.*

Réseau expérimental

Dans le cadre du programme "Génétique et Amélioration des Arbres Forestiers Méditerranéens", la Station d'Amélioration des Arbres Forestiers de l'I.N.R.A. a progressivement mis en place entre 1972 et 1978 son programme sur les Cèdres (ARBEZ & al., 1978). Actuellement, 23 dispositifs expérimentaux sont implantés dans 5 départements de la France méridionale (Var, Alpes-de-Haute-Provence, Drôme, Hérault, Aude). Les expérimentations sont réparties sur 12 stations différentes et couvrent des conditions écologiques très variées (altitude : 100 à 600 m; pluviométrie annuelle : 400 à 1200 mm; roche mère : calcaire, siliceuse; sols : carbonatés ou acides). Au total, plus de 71 000 plants sont installés sur 31 hectares et suivis individuellement.

Le réseau de l'I.N.R.A. est le plus important de ceux existant actuellement. Il permet la comparaison de 71 provenances parmi les quatre espèces de Cèdres, l'accent étant mis sur les 3 espèces du Bassin méditerranéen :

Provenances de *C. atlantica*	:	55
dont	:	29 du Maroc
	:	22 de France (artificielles)
	:	4 d'Algérie
C. libani	:	10
dont	:	6 du Liban
	:	3 de Turquie
	:	1 de Syrie
C. brevifolia	:	2 de Chypre
C. deodara	:	4
dont	:	3 d'Afghanistan
	:	1 de l'Inde

On remarquera que les provenances de *C. atlantica* d'Algérie et de *C. libani* de Turquie sont encore insuffisamment représentées dans le réseau français.

D'autre part, une plantation comparative de 30 descendances maternelles de Cèdre de l'Atlas, récoltées au Mont-Ventoux, a été mise en place; elle permettra une première étude des paramètres génétiques de cette espèce.

Principaux résultats obtenus

Une récente analyse de l'ensemble des données récoltées depuis 12 années a mis en évidence une très forte variabilité entre espèces et aussi entre provenances (MILLE, 1986).

Le Cèdre de Chypre (*C. brevifolia*) est caractérisé par une croissance très lente et ne semble donc pas d'intérêt forestier pour la France.

Les provenances syriennes et libanaises de *C. libani* se caractérisent par un débourrement végétatif précoce et une croissance lente, ce qui les rend peu intéressantes pour le forestier. Par contre, les provenances turques de cette espèce manifestent la meilleure croissance observée sur les argiles de décalcification, et ceci, même à basse altitude. D'autre part, les provenances testées de *C. libani* semblent manifester une meilleure résistance ou adaptation à la sécheresse, mais elles présentent une assez faible performance sur sols siliceux.

Les meilleurs résultats sont obtenus, en moyenne, avec des provenances de *C. atlantica* du Moyen Atlas (Maroc) et les provenances artificielles françaises, supposées originaires d'Algérie. Les provenances françaises, classées parmi les plus vigoureuses, sont stables sur tous les types de substrats, calcaires ou siliceux, la meilleure vigueur étant observée sur substrat siliceux.

Les résultats de l'I.N.R.A. ont également permis le classement de certains peuplements dans la catégorie des matériels "testés" :

- MONT-VENTOUX (Vaucluse) : 80 ha
- MENERBES (Vaucluse) : 90 ha
- SAUMON (Alpes-de-Haute-Provence) : 12 ha.

Perspectives de sélection et d'amélioration

- Evaluation des possibilités de gain génétique par sélection d'individus (croissance, débourrement, branchaison, qualité du bois dans l'optique d'une production de bois d'oeuvre de qualité).

- Préservation des meilleurs pools génétiques artificiels français (collaboration avec le C.E.M.A.G.R.E.F. et l'O.N.F.).

- Exploration de la variabilité inter- et intraspécifique des cèdres en Turquie et en Algérie.

- Exploration de l'intérêt des hybrides interspécifiques.

- Installation de dispositifs expérimentaux (provenances, tests de descendances) également en France non méditerranéenne (Midi-Pyrénées, Poitou-Charentes, Bourgogne, etc...).

- Transformation de certaines plantations comparatives de provenances de l'I.N.R.A. en sources de graines par éclaircies sélectives.

CROISSANCE, PRODUCTION ET SYLVICULTURE

Régénération naturelle

La fréquence et l'abondance des fructifications du Cèdre ont conduit en l'espace d'un siècle, à partir de quelques peuplements d'une dizaine d'hectares, à la colonisation progressive de vastes surfaces de maigres taillis de Chêne pubescent et de Chêne vert sur le Mont-Ventoux et le Petit Lubéron en Provence calcaire.

Une bonne année de fructification n'est cependant pas synonyme d'une régénération naturelle acquise, qui dépend étroitement des conditions climatiques et de la réceptivité du sol. En effet, pour assurer la dissémination des graines avant le printemps, une période humide suivie de gel et de dégel est nécessaire. Le Cèdre, comme la plupart des Pins et les Mélèzes, est une essence pionnière, dont la germination des graines et l'installation des semis sont favorisées par un sol minéral, humide et meuble et par une faible concurrence herbacée. On observe d'ailleurs souvent d'abondantes régénérations naturelles de Cèdre et de Pin noir d'Autriche (*Pinus nigra* Arn. ssp. *nigricans* Host.) sur des surfaces récemment incendiées. Les semis restent très sensibles à la sécheresse et aux gelées tardives pendant les premières années.

En Provence calcaire, il est plutôt rare de voir des bouquets de Cèdre ou des arbres isolés sans semis naturels à proximité. Par contre, dans le massif du Rialsesse, sur sol cristallin, les peuplements très haut et denses produisent peu de graines saines et la couche d'humus jointe à la forte concurrence herbacée entravent l'installation de la régénération.

Régénération artificielle

La reconstitution de la forêt méditerranéenne, que se soit des surfaces incendiées ou par transformation de taillis, nécessite le reboisement de surfaces importantes par plantation; le semis direct, grand consommateur de graines, n'est plus guère employé. Les difficiles conditions écologiques demandent de porter une très grande attention au choix du matériel végétal (espèce, provenance, variété), aux techniques d'élevage des plants (qualité), à la préparation du sol, aux techniques de plantation et d'entretien. Planter est toujours très coûteux et de nombreuses recherches ont été entreprises visant à améliorer la réussite des plantations tout en maintenant leurs coûts dans des limites acceptables.

Au cours des années cinquante, plusieurs grands chantiers-pilote de reboisement ont été mis en place dans différentes zones, mettant en comparaison des techniques variées de préparation du sol. Après 30 années d'observation il s'avère qu'un sous-solage profond (60 à 70 cm) apporte un gain non négligeable de taux de survie et de croissance en hauteur pendant les premières années. Ce gain de croissance, qui peut atteindre une classe de fertilité, s'estompe progressivement sur les stations défavorables. La suppression de la strate arbustive ou herbacée par broyage ou par décapage s'avère parfois nécessaire; le brûlage dirigé pourrait, dans l'avenir, constituer une solution peu onéreuse pour remplacer partiellement ces méthodes mécaniques.

Pour assurer une meilleure reprise, l'utilisation de plants à racines nues est progressivement abandonnée au profit de plants élevés en conteneurs pendant 7 à 8 mois en pépinière. La Division "Techniques Forestières Méditerranéennes" (TFM) du C.E.M.A.G.R.E.F. d'Aix-en-Provence expérimente, en coopération avec l'I.N.R.A., différents types de conteneurs et de substrats ainsi que des techniques d'élevage en pépinière, pour optimiser l'adéquation "taux de reprise * coût d'élevage et de plantation" (GUEHL & al., 1989). Les premières conclusions pratiques sont les suivantes :

- Utilisation d'un conteneur sans fond d'un volume au moins égal à 400 cm^3 et d'une section supérieure à 20 cm^2 (par ex. modèle WM).

- Elevage par surélévation d'au moins 10 cm par rapport au sol.

- Réduction maximale de la durée du séjour en conteneur pour limiter les déformations racinaires.

- Les substrats artificiels composés d'un mélange binaire tourbe blonde et écorce de pin ou tourbe blonde et argile expansée ont donné de meilleurs résultats (reprise et croissance) que les substrats classiques contenant une proportion importante de terre.

- Les plantations se font de préférence en automne pour que les plants puissent profiter de la période des pluies.

Dans ce même contexte on étudie également la mycorrhization contrôlée des plants en pépinière.

Croissance juvénile

Plusieurs auteurs ont analysé la croissance de jeunes reboisements ou régénérations naturelles dans la région. Ils observent une variabilité très importante qui ne peut être expliquée par les seules conditions écologiques. En effet, l'origine et la qualité du matériel végétal qui étaient souvent inconnues, les différentes techniques de préparation du sol et de plantation utilisées, mais également les conditions climatiques à la plantation et pendant les premières années de croissance contribuent probablement d'une manière importante et complexe à cette variabilité. Ceci explique également les difficultés et la grande incertitude que l'on éprouve quand il s'agit de prédire la classe de productivité d'un jeune boisement. BOUVET (1985) propose néanmoins une grille de classement pour les reboisements jusqu'à l'âge de 20 ans, basée sur la relation Hauteur dominante / Age. La figure 2 montre la différence de croissance en hauteur entre une régénération naturelle après incendie (on remarquera l'excellente croissance) - et une régénération naturelle et une plantation après sous-solage (plants élevés en sachet de polyéthylène) dans une formation ouverte de taillis de Chêne pubescent. Il est à noter que les semis naturels et les plants de la plantation ont la même hauteur. Ces deux stations se trouvent à peu de distance l'une de l'autre sur le versant sud du Mont Ventoux. Elles se trouvent dans les mêmes conditions climatiques, mais la station incendiée est sur un sol plus profond.

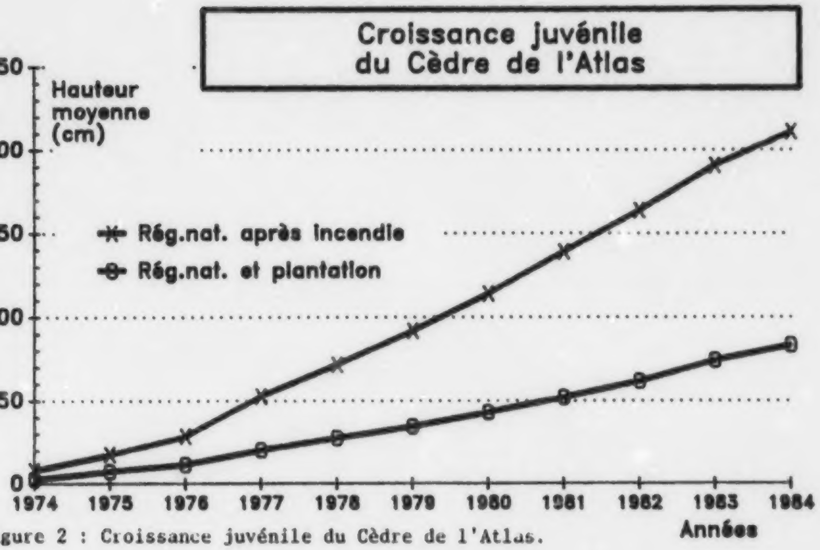


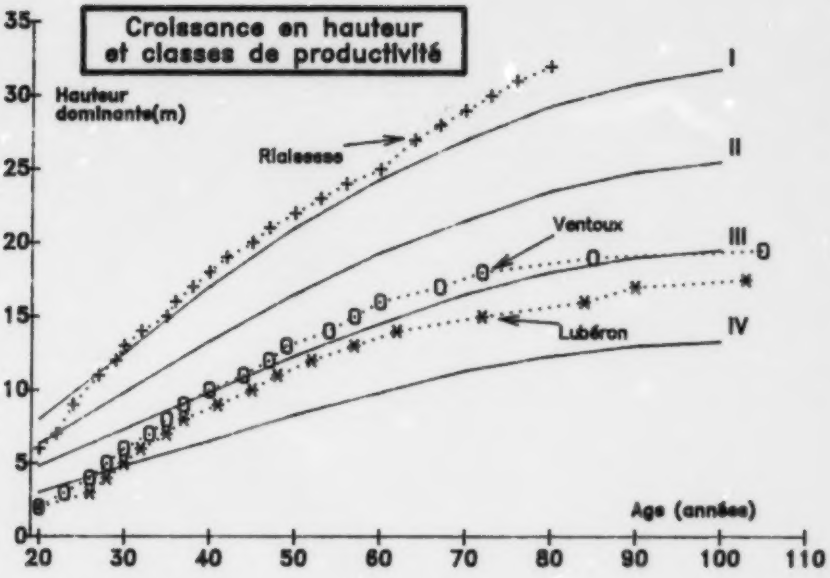
Figure 2 : Croissance juvénile du Cèdre de l'Atlas.

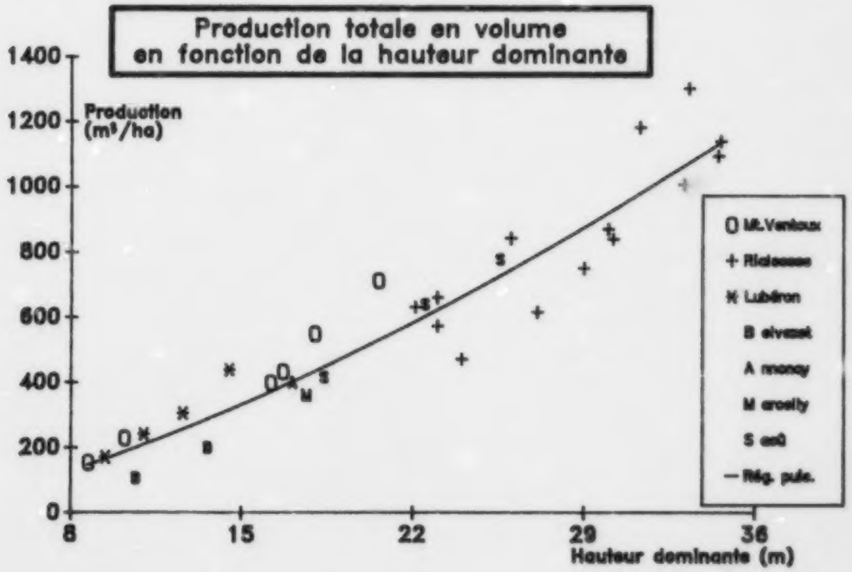
Croissance et production des peuplements

La Station de Sylviculture Méditerranéenne de l'I.N.R.A. gère un réseau d'une vingtaine de placettes permanentes et semi-permanentes, dont certaines sont suivies depuis plus de 50 ans. Quelques couples de placettes permettent la comparaison de différentes modalités d'éclaircie.

Ce réseau de placettes, encore nettement insuffisant, et des analyses de tiges ont néanmoins permis d'établir provisoirement un faisceau de courbes de croissance (hauteur dominante en fonction de l'âge) et une relation entre production totale en volume et hauteur dominante (TOTH, 1973). Ces relations sont présentées dans les figures 3 et 4.

A cet égard, il faut noter le grand éventail des productivités potentielles constatées à l'âge de 100 ans, allant de 33 m de hauteur dominante à RIALSESSE dans l'Aude, à 21 m de hauteur dominante sur le versant sud du MONT-VENTOUX (Vaucluse). Les productions totales en volume sont respectivement de 1200 m3/ha et de 700 m3/ha. Cette différence est encore plus importante pour la valeur sur pied de ces peuplements : le rapport est alors de l'ordre de 3 à 1. Les figures 5 et 6 présentent les données dendrométriques relatives à ces deux peuplements et montrent la distribution des tiges sur pied par classes de diamètre. La placette permanente de Rialsesse, suivie depuis 1934, a été éclaircie assez fortement, tandis que le peuplement du Mont-Ventoux, qui fait partie des premières plantations, n'a été que faiblement éclairci.


Croissance en hauteur
et classes de productivité
Hauteur
dominante(m)
Ventoux
Lubéron
I
II
III
IV
Age (années)
0
5
10
15
20
25
30
35
20
30
40
50
60
70
80
90
100
110


Production totale en volume
en fonction de la hauteur dominante
Production
(m³/ha)
Mt.Ventoux
Lubéron
0
200
400
600
800
1000
1200
1400
8
15
22
29
36
Hauteur dominante (m)

La Division T.F.M. du C.E.M.A.G.R.E.F. procède actuellement à un découpage de la région méditerranéenne française en régions naturelles homogènes du point vue climat et substrat (roche mère) et aborde les études de typologie et de cartographie de stations, ainsi que de liaisons production/station pour les principales espèces de reboisement(OSTERMEYER, 1984).

Sylviculture

De ces différences de productivité découlent tout naturellement des objectifs de production très différents : production de bois d'oeuvre de qualité, enrichissement des taillis de chênes, forêt de protection (érosion, incendie), forêt de loisir et de détente, agroforesterie (sylvopastoralisme), etc...

Depuis les années 50, les espacements à la plantation ont progressivement diminué, passant de plus de 5000 à environ 1100 plants à l'hectare. Pour les peuplements de production, réservés aux meilleures stations, les plantations sont faites en lignes et en plein. L'introduction par bandes de deux lignes dans les taillis de Chênes permet de maintenir une protection des sols plus importante. La création de placeaux de dissémination (environ 50 arbres par placeau et par hectare) permet à terme d'enrichir les formations végétales claires et peu productives sans investissement initial important. L'installation et l'entretien de ces placeaux sont toutefois difficiles et il est préférable de les remplacer par une ligne de dissémination tous les 100 m.

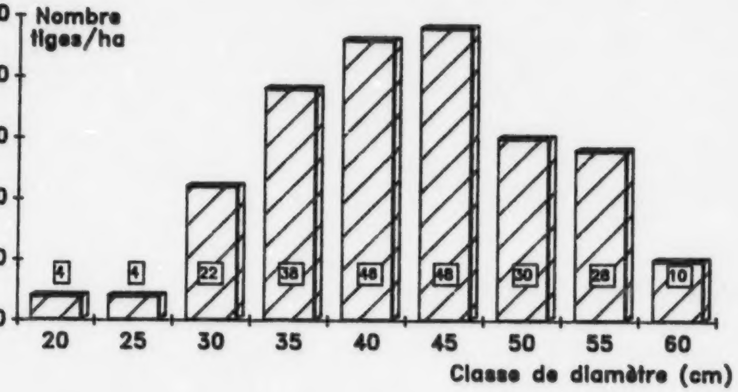
Dans les boisements de protection, où l'on cherche une fermeture rapide du couvert, notamment dans les secteurs à haut risque d'incendie, la densité initiale de plantation doit être plus élevée (environ 2500 tiges à l'ha).

Des données quantitatives et précises sur la conduite des peuplements, font encore gravement défaut. Dans les peuplements anciens, plantés à très forte densité, les éclaircies, pratiquées d'une manière assez irrégulière, ont été plutôt très faibles à modérées. Bon nombre de jeunes peuplements arrivent maintenant au stade de la première éclaircie et une sylviculture plus dynamique reste à mettre au point et à expérimenter.

Les peuplements de production sont généralement traités en futaie régulière à l'exception de quelques peuplements anciens, souvent mélangés et issus de régénération naturelle qui sont aménagés en futaie par parquet d'environ un hectare. L'âge d'exploitabilité varie selon les stations de 80 à 100 ans et on cherche à obtenir un diamètre moyen de 45 à 50 cm.

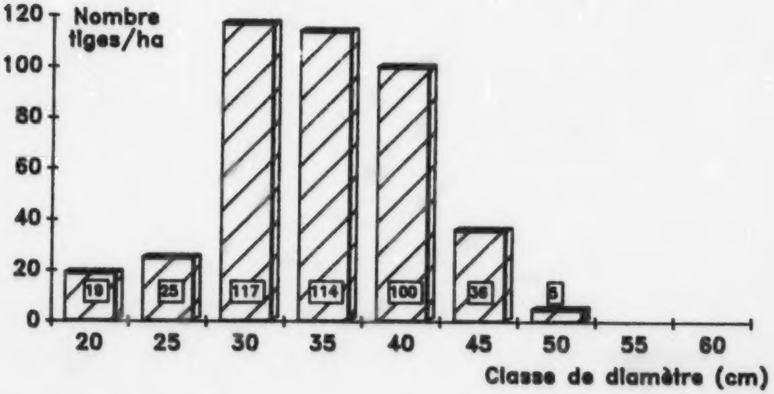
Forêt domaniale de Rialsesse (11)

Age années	Haut.dom (m)	Haut.moy (m)	Diam.dom (cm)	Diam.moy (cm)	Nombre tiges/ha	Surface m²/ha	Volume m³/ha	V. moy m³	Production m³/ha
99	33.0	31.5	51	44	230	34.3	599	2.60	1166



Forêt communale de Bédoin (84)

Age années	Haut.dom (m)	Haut.moy (m)	Diam.dom (cm)	Diam.moy (cm)	Nombre tiges/ha	Surface m²/ha	Volume m³/ha	V. moy m³	Production m³/ha
103	20.6	19.4	42	31	416	31.4	378	0.91	712



Perspectives

En ce qui concerne la sylviculture, des études sur la croissance juvénile des régénérations naturelles ont été commencées. Des dispositifs expérimentaux modernes, où seront étudiés les effets de divers traitement sylvicoles (dépressage, éclaircie), sont en cours d'installation sur différentes stations. Un tarif à deux entrées pour le cubage d'arbres (volume bois fort tige), valable pour le Cèdre de l'Atlas dans toute la France, vient d'être construit par l'I.N.R.A.; il utilise l'ensemble de données disponibles à l'I.N.R.A. et à l'Inventaire Forestier National (COURBET, 1990).

La déprise agricole et l'extension du sylvopastoralisme nécessiteront, dans le cadre d'une utilisation multiple des espaces naturels, des recherches nouvelles sur la croissance d'arbres plantés à très large espacement et soumis uniquement à la compétition de la strate arbustive ou herbacée.

Une extension du réseau de placettes, prévue en collaboration avec l'Office National des Forêts, et l'intensification des mesures et observations permettront à moyen terme, à l'horizon de l'an 2000, de mettre au point des "modèles de gestion", permettant aux gestionnaires de choisir parmi un large éventail de traitements sylvicoles tenant compte des contraintes biologiques et économiques.

La bonne productivité, l'excellente adaptation aux conditions écologiques méditerranéennes et la bonne qualité de son bois conféreront au Cèdre une importance économique certaine dans la filière-bois de la région méditerranéenne française. Des marchés locaux de bois de Cèdre se constituent d'ailleurs progressivement dans les grands massifs d'introduction ancienne (Vaucluse, Aude).

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LE CEDRE DE L'ATLAS

REPARTITION, CROISSANCE ET TRAITEMENT SYLVICOLE

Omar M'HIRIT
Professeur de sylviculture, Ecole Nationale
Forestière d'Ingénieurs, Salé, Maroc.

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SUMMARY

This paper discusses the geographical repartition, the bio - climate, the phyto - edaphic and the auto - ecological aspect and the silviculture practice of the Atlas cedar (*Cedrus atlantica* Manetti)which is a specie growing essentially in the North Africain mountains.Poroduction tables and growth models have been developped for both natural and mane-made cedar forest. Also some silvicultural and planning techniques for North Africain forest, which is under the range constraint, are outlined.

INTRODUCTION

Le genre "*Cedrus*" (famille des *Pinaceae*, sous-famille des *Abieteae*) comprend plusieurs espèces dont la valeur taxonomique a été longtemps controversée. Intégrés d'abord dans une seule espèce (*C.libanotica*, link), les cèdres ont évolué vers la distinction en quatre espèces répondant à des critères biogéographiques,qui fait actuellement l'unanimité de la plupart des dendrologues:*Cedrus atlantica* Manetti(1844);*Cedrus libani* Barr. 1838; *Cedrus brevifolia* HENRY ; *Cedrus deodara* Loudon (1838).

Le cèdre , espèce essentiellement montagnarde , occupe des surfaces d'importance inégale et forme spontanément trois blocs géographiques distincts: Afrique du Nord-Asie mineure-Himalaya. Le premier bloc représenté par *Cedrus atlantica* Manetti, comprend : l'Atlas marocain (130.000 ha) le Rif (15.000 ha)et l'Atlas algérien (40.000 ha).Le deuxième bloc se divise en deux parties occupées chacune par une espèce particulière:*Cedrus libani* Barrel (1.700 ha)au Liban, quelques centaines d'ha en Syrie et plus de 160.000 ha en Turquie dans le Taurus et l'Amarus entre 1.500 m et 2.000 m d'altitude; *Cedrus brevifolia* Henry,dans l'île de chypre, en forêt de Paphos sur une surface très restreinte. Le troisième bloc, avec *Cedrus deodara* Loudon , représente les grandes massifs de l'Inde et de l'Afganistan sur le nord-ouest de l'Himalaya entre 1.350 et 3.500 m d'altitude.

Le cèdre de l'Atlas en Afrique du nord s'organise en sept ensembles distincts du point de vue phytogéographique.Le présent article, après une esquisse de la répartition actuelle de cette espèce,présente son écologie sous un angle bioclimatique , phyto-édaphique et autoécologique, éléments qui conditionnent la sylviculture et la production du cèdre et des cédraies.

REPARTITION ACTUELLE DU CEDRE DE L'ATLAS

Le cèdre de l'Atlas s'organise en sept blocs distincts d'inégale importance en Afrique du nord dont quatre dans les montagnes marocaines:les cédraies du Rif,du Moyen Atlas oriental et central et du Haut Atlas oriental;et trois dans les montagnes algériennes: les cédraies de l'Ouarsenis, des Aurès et du Djurdjura (*figure 1*).

L e C è d r e d a n s l e R i f

Le cèdre dans le Rif occupe 15.000 ha environ dans la zone axiale de la chaîne rifaine . Il se développe d'une manière sporadique dans les niveaux supérieurs de la chaîne numidienne et plus particulièrement au Jbel Bouhachem dans les endroits impropres aux chênes caducifoliés(*Quercus canariensis* , *Quercus pyrenaica*) à partir des altitudes 1.400 m et sur les versants exposés au Nord-Ouest. (Emberger 1939; Ruiz de la Terre 1956,Lecompte 1973 ; M'Hirit 1982).

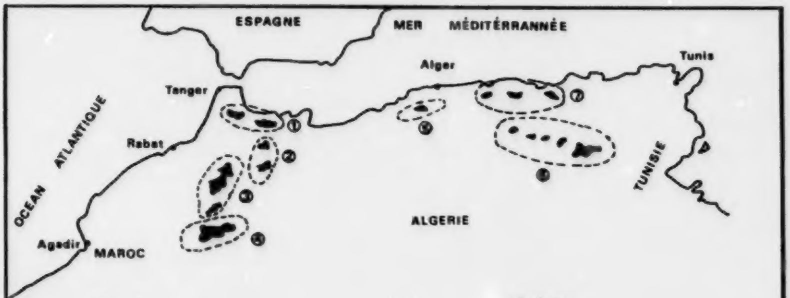
Dans la dorsale calcaire le cèdre se trouve en concurrence avec le sapin du Maroc (*Abies maroccana*)dans son aire optimale (1.500-1.900 m).Si le sapin domine à ces niveaux altitudinaux, il cède la place au cèdre aux altitude élevées , où cette espèce forme des peuplements, pures quoique clairsemés, culminant au Jbel Lakrâa à 2.118 m d'altitude.

Dans la partie centrale de la chaîne le cèdre forme de belles futaies essentiellement sur substrat non calcaire . Les massifs s'individualisent d'Ouest en Est en bandes presque parallèles découpées par de larges vallées ou replats . Ils succèdent tantôt aux chênes caducifoliés , le chêne tauzin (*Quercus pyrenaica*) dans les massifs de Tizirène , tantôt au chêne zeen (*Quercus faginea*)dans le versant septentrional du massif de Tidighine, mais plus fréquemment aux couples chêne vert-chêne liège (*Quercus rotundifolia* , *Quercus suber*).. Il disparaît vers l'Est au niveau de Jbel Iguermalet et au Jbel Tizi-Ifri . Dans cette partie de la chaîne le cèdre se développe dans les expositions Nord et Nord-Est,de préférence à partir de 1.500m d'altitude,sur des substrats quartzito-schisteux de la nappe de Kétama et sur des substrats gréseux de la nappe de Tizirène, reposant sur des stratifications marno-calcaires de la base du crétacé.

Le Cèdre dans le Moyen Atlas

Le cèdre dans l'atlas comprend quatre ensembles:la cédraie du Tazzeka, le groupe du Moyen Atlas central, le groupe du Moyen Atlas oriental . et le groupe du Haut Atlas oriental.

La cédraie du Tazzeka occupe quelques centaines d'hectares (850 ha)



Maroc

1. cédraies du Rif
2. cédraies du Moyen Atlas Oriental
3. cédraies du Moyen Atlas Central
4. cédraies du Haut Atlas Oriental

Algérie

5. cédraies de l'Ouarsenis
6. cédraies des Aurès
7. cédraies du Djurdjura

Figure 1 : Répartition actuelle du cèdre de l'Atlas

sur le sommet de Jbel Tazzeka au dessus de 1.750 m sur un substratum de shistes primaires non calcaires.Dans le versant sud le cèdre se développe sous forme de tâches de rajeunissement où les semis s'installent dans les plages écorchées à helianthème(*Helianthemum helianthemoides*).Les versants nords, très pentus, sont occupés par des futaies denses dont la régénération envahit les taillis de chêne vert à la limite inférieure de la cédraie. Cette cédraie très humide présente beaucoup d'affinités avec celles du Rif.

Les cédraies du Moyen Atlas central représentent l'ensemble le plus important du cèdre de l'Atlas. La nature calcaire ou dolomitique du substratum (*Lias et Jurassique*) donne une grande unité à de très grandes ensembles forestiers. On distingue, au nord le groupe du Causse Moyen atlasique tabulaire et au sud le groupe du Moyen Atlas plissé constitué par des reliefs mieux individualisés et d'altitude plus élevée (Emberger 1939; Pujos 1966 ; Lecompte 1969 ; Peyre 1979 ; Achhal et al. 1980).

Les massifs du Causse culminent aux environs de 2000 m (Sidi Mguild, 2010 m; Michlifen 2085 m; Ich ou Harroq 2050 m). Les forêts d'Azrou et de Sidi Mguild occupent essentiellement les séries dolomitiques et calcaires du Lias inférieur (*Sinemurien-Lotharingien*) et moyen (*Pleinsbachien et Domerien*). Le massif d'Ajdir constitue la séparation entre Causse et Moyen Atlas plissé. Les massifs s'organisent d'Est en Ouest en plusieurs ensembles individualisés dans la chaîne plissée: la forêt d'Aïn Nokra à l'Est, la forêt d'Arhbal ou Larbi, le massif d'Itzer, de Bekrit, de Sénoual, d'Ajdir, et de Talarine.

Les cédraies du Moyen Atlas oriental s'individualisent dans les massifs du Bou Iblane, de Taffert et de Tamtroucht au nord et dans les massifs de Bou Naceur-Gueb-er-Rahal au sud. Dans le Bou Iblane la cédraie de Jbel Bou Melloul est constituée par des îlots denses sur dolérite entre 1800 m et 2000 m; la cédraie de Tine Mellet, sur substratum marno-calcaire de Toarcien-Aalérien, se présente sous forme de vieille futaie équienne. Plus à l'Est s'étendent les vastes cédraies du versant nord de Jbel Nerkibat. Au nord, dans la région de Tamjout à Tamtroucht au pied du Jbel Moussa ou Salah, se développement de magnifiques cédraies en régénération. Dans ce secteur l'étagement est tout à fait caractéristique et les oppositions de versants sont particulièrement remarquables (Peyre 1979 ; Ziat 1987).

Le cèdre dans le Haut Atlas

Les cédraies du Haut Atlas oriental se développent sur les versants nord du Jbel Ayachi sous forme de belles futaies et de vieilles futaies d'altitude. Le Jbel Masker et ses prolongements occidentaux portent de vastes futaies très dégradées sur marno-shistes calcaire. Ces massifs présentent des analogies climatiques et édaphiques avec les cédraies du Bou Iblane (Emberger 1939 ; Quezel 1957 ; Quezel et al. 1987).

Le Cèdre dans l'Atlas Algérien

Le cèdre dans l'Atlas algérien comprend trois ensembles : le groupe de l'Ouarsenis, le groupe des Aurès et le groupe du Djurjura.

Le cèdre dans l'Ouarsenis

Dans le massif de l'Ouarsenis,dans l'est algérien, le cèdre apparaît dans l'Atlas mitidjien-ou Atlas de Blida-(1040 ha)et dans celui de Teniet El Had (960 ha). L'Atlas de Blida s'élève à plus de 1200 m. Il comprend les montagnes des Beni Miscera , des Beni Salah , des Beni Messaout et du Koudiat Chrea (1515 m) constitué de marnes argilo-shisteuses du Cretacé inférieur (Neocomien) ou moyen . Le cèdre (massif de Beni Salah) se développe sur les shistes et quartzites du Néocomien.Dans le massif de Teniet El Had , rattaché au système ouarsenien , la forêt de cèdre se trouve sur grès médjanien de l'éocène supérieur (Faurel 1947 ; Boudy 1955).

Le cèdre dans les Aurès

L'Aurès est une montagne crétacée qui culmine à 2328 m.Elle est prolongée à l'ouest par la chaîne du Hodna et constitue un ensemble pittoresque avec de longues lignes de crêtes rectilignes séparées par des vallées profondes et des gorges étroites . On y trouve les sommets les plus élevées de l'Algérie : mont Chelia (2328 m); mont Mahmel (2321 m); mont Amamra (2149 m); mont Aïdel (2147 m) mont Toggourt (2094 m). Le cèdre est groupé en deux masses principales : l'un à l'ouest près de Batna avec la forêt de Bélezma sur les flancs de Jbel Toggourt (8100 ha),l'autre à 50 km à l'est près de Khenchela dans le massif des Beni Oudjana sur 3000ha(mont Chélia) et des Ouled Yacoub (3000 ha) et (Dj. Faraoun , Dj. Aidel). Entre ces deux ensembles , se trouvent des cédraies moins importantes du Sgag (600 ha),du Dj. Azreg (2600 ha) et du Ras Ichmoul (150 ha). Dans les montagnes gréseuses du Hodna, recouverte autrefois de vastes forêts de cèdre dont il ne reste plus que quelques îlots isolés,particulièrement au Righa dahra dans le sommet de J.Guedil,(150 ha), à Bou Taleb dans le J. Afghane (2500 ha)et dans la forêt de Guethian (1000 ha). En général, le grès forment le substratum des forêts de cèdre de l'Aurès : Chélia, Belezma , Bou Taleb etc... Le massif de Sgag se développe sur dolomie et calcaire dolomitique du Jurassique supérieur et dans le calcaire du Cretacé inférieur. (Faurel et al. 1949 ; Abdessamed 1981).

Le cèdre dans le Djurdjura

Le Djurdjura est un puissant massif calcaire de 60 km de long avec des sommets de plus de 2000 m (Jbel Haizer 2132 m , Jbel Abouker 2305 m, Jbel Lalla Khédija 2308 m). Le cèdre se développe particulièrement dans le massif des Babors , région la plus pittoresque et la plus arrosée de l'Algérie,avec deux sommets principaux: Mont Babor (2006 m) et mont Tababor (1965 m) . Il apparaît par tâche à partir de 1300 m sur les versants nord du Djurdjura (50 ha) et dans les forêts de Babors (1500 ha) ou il se mélange au Sapin de Numidie , seule station en Algérie de 250 ha sur des substratum calcaires du Crétacé (couches cénomaniennes à base de marnes, de shistes et grès avec de nombreux îlots du Lias).La cédraie de Djurdjura présente beaucoup d'affinités avec celles du Rif occidental (Boudy 1955; Barbero et al. 1975).

ECOLOGIE DU CEDRE DE L'ATLAS

B i o c l i m a t   e t   é t a g e s   d e   v é g é t a t i o n

De nombreuses études ont été consacrées à l'étude et la caractérisation bioclimatique du cèdre et des cédraies (Emberger 1939 , Faurel et Laffite 1949,Pujos 1966,Lepoutre 1966, Delannoy et al. 1974, Quezel 1976, Donadieu 1977,Peyre 1978,Abdessamed 1981,Benabid 1982,M'hirit 1972,1982). Le cèdre de l'Atlas occupe essentiellement les variantes fraîches à extrêmement froides des ambiances bioclimatiques perhumides , humides , et subhumides selon la classification d'Emberger (Sauvage 1963).La valeur du cœfficient d'Emberger (Q2) varie de 50 à 330 alors que la température moyenne minimale du mois le plus froid varie entre -1°C et -9°C.

Le cèdre de l'Atlas, à tendance à s'organiser en ceintures altitudinales correspondant à des étages de végétation. Cependant les limites altitudinales varient entre les ambiances bioclimatiques et à l'intérieur d'une même ambiance en raison de la grande hétérogéneité des conditions climatiques,géomorphologiques,de l'instabilité et de la vulnérabilité des cédraies (Benabid 1982) . La *figure 2* présente la situation bioclimatique du cèdre de l'Atlas au sens d'Emberger et altitudinale au sens de Quezel. Elle s'étend de l'étage méditerranéen supérieur à froid dans les Aurès,le moyen Atlas tabulaire et le Rif occidental à l'étage oroméditerranéen extrêmement froid dans le Haut Atlas;mais son optimum bioclimatique correspond à l'étage montagnard-méditerranéen entre 1600 m et 2000 m.

Les caractéristiques ombrothérmiques des cédraies de l'Afrique du Nord sont données dans le tableau ci-après :

Tableau 1 : Caractéristiques ombrothermique du cèdre de l'Atlas.

type de cédraie	latitude (N)	limites altitudinales(m)	précipitations annuelles(mm)	températures extrêmes °C	
				(M)	(m)
Rif occidental	35°01-35°53	1400à2300	1390à1786	28,3°à24,1°	-5,6°à0,2°
Rif central	34°55-35°35	1500à2400	1257à1707	28,8°à23,7°	-5,6à-0,4°
Rif oriental	35°50à35°07	1700à2200	906à1311	26,9°à24,6°	-5à-1,8°
Moyen Atlas tabulaire	33°08-33°44	1500-2000	871à1066	30,9°à27,6°	-4,7à-0,5°
Moyen Atlas oriental	32°36-33°05	1800-2000	615à 927	28,7°à26,5°	-6,4à -3
Haut Atlas oriental	32°16-32°53	1800-2400	499à 799	29,6°à23,2°	-8,3à-3,1°
Aurès	35°30	1350-2300	499à 790	29,6°à23,2°	-8,3à-3,1°

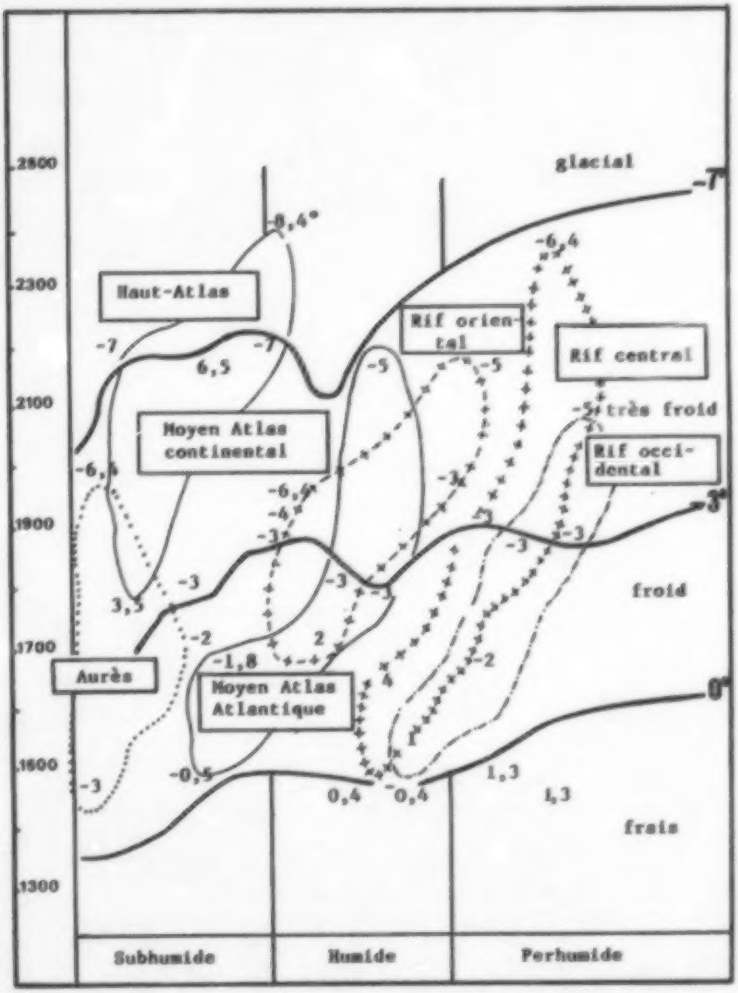


Figure 2: Place du cèdre dans le système Emberger-Quezel.

Originalité phyto-édaphique du cèdre

Le cèdre de l'Atlas individualise en Afrique du Nord un certain nombre de groupements végétaux variés dans une amplitude altitudinale importante à partir de 1500 m dans le Rif et les Aurès , 1600 m dans le Moyen Atlas et les Babors,1700 m dans le Haut Atlas oriental jusqu'à 2440 m. au sommet de Tidghine dans le Rif ou 2328 m au mont Chelia voire 2600 m dans le Moyen Atlas oriental, (Barbero et al. 1975 , Phipps et al. 1978, Peyre 1979,Barbero et al. 1980, Abdessamed 1981,M'hirit 1980,1982,Zeraia 1986). Ces groupements s'intégrent , d'après leurs critères floristiques et en fonction de leurs exigences écologiques,soit dans l'ordre des *Quercetalia ilicis*, soit dans la classe des *Quercetea pubescentis* et dans l'ordre des *Quercus Cedretalia atlanticae* (Barbero et al. 1974,1980). Cette discrimination ne répond pas seulement à des caractères altitudinaux , mais elle est aussi en rapport avec la structure et la densité de la forêt , l'état de conservation du sol,voire du substrat. D'une manière générale les communautés végétales du cèdre de l'Atlas sont définies en fonction du bioclimat,de l'étagement altitudinal et du substrat et peuvent être classées de la façon suivante :

(i) les communautés végétales de la cédraie-sapinière dans le Rif (*Abies maroccana-cedrus atlantica*) et dans les Babors (*Abies numidica-cedrus atlantica*)avec *Taxus bacata, Ilex aquifolium ; Quercus mirbekii, Acer granatense, Acer obtusatum* sur les Babors...

(ii) les communautés végétales de la cédraie à chêne vert avec *Ilex aquifolium et Acer monspessulanum.*

(iii) les communautés de la cédraie mésophile dans le Moyen Atlas,le Rif, l'Ouarsenis où dominent les espèces *Argyrocytisus battandieri , Ilex aquifolium.*

(iv) les communautés de la cédraie orophile dans la dorsale calcaire du Rif , du Moyen Atlas oriental et les Aurès avec des genevriers: *Juniperus thurifera et Juniperus oxycedrus* et des xérophites épineux.

L'originalité édaphique du cèdre de l'Atlas réside, tout particulièrement dans sa rusticité et son indifférence à la nature lithologique du sol. Le cèdre se rencontre sur des substrats et des sols variés : sur des basaltes, de la dolérite, des marno-calcaires, des marno-shistes, des dolomies,des calcaires dolomitiques, des shistes et des grès, au Maroc; sur des grès blancs,des dolomies, des calcaires francs, des calcaires dolomitiques et des marnes en algérie . Les types de sols rencontrées dans les cédraies sont du type fersiallitiques sur calcaire , rendzine magnésienne sur dolomie , andosolique sur basalte , ocre-podzolique sur grès avec une grande richesse en matière organiques et en fer. Mais,si le cèdre est indifférent à la nature chimique du substrat , il n'en est pas de même à l'égard de la structure physique, particulièrement, vis-à-vis de la régénération (Faurel 1947, Lepoutre 1961, Maurer 1968, Lecompte et al. 1975).

C o m p o r t e m e n t   a u t o é c o l o g i q u e

Les recherches dans ce domaine sont mises en œuvre particulièrement en France et en partie au Maroc . Elles concernent surtout les problèmes d'adaptation à la sécheresse; les relations entre état hydrique et photosynthèse en fonction de différents facteurs climatiques ; les rythmes de croissance racinaire et aérienne ; le débourrement; la dendrochronologie; les mycorhizes; la nutrition minérale ; la biologie florale . De nombreux résultats sont obtenus et publiés dans ce domaine;ils permettent de mieux appréhender le comportement et les mécanismes écophysiologiques qui régissent la croissance du cèdre et peuvent servir de bases aux recherches génétiques et sylvicoles (Boulard 1957, Lepoutre 1961 , Riedacker 1978,Ducrey 1981, Finkelstein 1981, De Vitry 1982,Abourouh 1983, Aussenac et al. 1981, 1982, 1983, Guehl 1985, Till 1985, Targui 1986).

Dans les conditions expérimentales contrôlées la limite de la photosynthèse du cèdre de l'Atlas se situe autour de -8°C à -9°C.Mais il maintient une activité photosynthétique et transpiratoire jusqu'à des niveaux de grandes sécheresse (-30 bars et -35 bars) contrairement aux pins qui bloquent leurs stomates vers -15 bars et -17 bars.

Le problème de la photosynthèse hivernale du cèdre en conditions naturelles n'a pas encore été étudiés. D'une manière générale, l'adaptation du cèdre aux basses températures est définie par trois caractéristiques : (i) la possibilité de photosynthétiser en hiver à un taux non négligeable par rapport à la photosynthèse estivale; (ii) la faculté de récupérer rapidement une photosynthèse normale après passage des températures voisines du point de congélation de leurs tissus; (iii) la possibilité de résister sans dommage à des températures très basses.

Les bourgeons de cèdre ont besoin,pour démarrer normalement,de subir l'action du froid puis de températures élevées comme la plupart des espèces ligneuses des régions tempérées . Le bourgeon terminal démarre le premier et presque en même temps que les bourgeons latéraux.La croissance aérienne alterne avec la croissance des racines.

La croissance en hauteur du cèdre peut être qualifiée de monocyclique. Elle se produit de façon générale pendant la nuit , mais lorsque le temps est couvert et pluvieux , elle peut se produire pendant la journée, cette croissance étant cependant toujours plus forte durant la nuit . Le seuil apparent de végétation (température moyenne journalière en dessous de laquelle la croissance est nulle) est égale à 6,6°C. Ce seuil est voisin de celui des autres espèces résineuses, *Abies alba*: 5,2°C, *Abies nordmaniana* 6,2°C, *Picea alba*:4,1°C, *Pseudotsuga menziezii*: 5°8C. Bien que montagnard dans son aire naturelle, le cèdre apparaît comme essence plus thermophile que les espèces citées précédemment.

D'une manière générale la durée moyenne de la période de croissance varie 0,7 mois à 3,4 mois suivant les régions et les altitudes . En plus elle est concentrée sur les mois de mai, juin et juillet.

Les études sur la nutrition minérale du cèdre sont à leur début de telle sorte que les premiers résultats doivent être considérés avec une certaines prudence.Le niveau de nutrition, pour les cédraies du Moyen Atlas , calculé pour chaque saison de l'année durant la période 1977 - 80 et pour 4 roches-mères: basalte; dolomie; calcaire; grès; varie autour d'une moyenne de 1,25 % pour l'azote, 0,123 % pour le phosphore, 0,58 % pour le potassium, 0,48 % pour le calcium, 0,29 % pour le magnésium.

Le niveau de nutrition en azote ,en potassium et en calcium passe par un minimum en été quel que soit le type de roche-mère.L'absorption atteint son maximum au printemps . L'assimilation en phosphore est généralement faible quelle que soit la saison sur tous les types de roches-mères (0,10 à 0,15 %), tandis que celle du magnésium est minimale en été (0,2 %) et reste stable durant les autres saisons.

En ce qui concerne le substratum l'absorption en potassium est généralement maximale sur roches éruptives où elle peut atteindre 0,67 % à 0,85 %.Par contre celle de l'azote du phosphore et du calcium ne présente pas de différence significative . L'absorption du Magnésium est maximale sur roches dolomitiques où elle varie de 0,4 % à 0,46 %, alors qu'elle ne dépasse guère 0,20 % à 0,35 %, sur les autres types de roches-mères.

SYLVICULTURE ET PRODUCTION

Dans les cédraies naturelles,de nombreuses études relatives à la régénération et à la conduite des peuplements ont été entreprises (Algérie, Maroc, notamment). Actuellement, les recherches sont orientées, notamment sur la connaissance de la productivité , l'établissement de modèles de croissance. Ces recherches ont abouti à l'établissement des tarifs de cubage pour les différents types de forêts naturelles,la construction de tables de production pour les cédraies du Rif et du Moyen-Atlas oriental marocain de l'Atlas de Blida et des Aurès et la proposition de modèles de simulation pour la gestion des cédraies irrégulières (Moyen Atlas).

Dans les pays d'introduction du cèdre,les centres de recherche gèrent des réseaux de placettes permanentes et semi - permanentes, notamment en France et en Italie . En France une vingtaine de placettes permettent des comparaisons d'éclaircies.En Italie comme en Grèce les résultats des premiers essais d'introduction sont très concluants tant au point de vue adaptation et comportement du cèdre dans différentes situations écologiques qu'au point de vue de la croissance(Toth 1973, YI Byonng 1976). En ce qui concerne la sylviculture proprement dite , il faut signaler le grand pouvoir de régénération naturelle du cèdre hors de son aire(Putod 1974). Cependant des données précises sur la conduite des peuplements (éclaircies, dépressages) font encore défaut.

P r o d u c t i o n   e t   m o d è l e s   d e   c r o i s s a n c e

Les études sur la production du cèdre ont débuté depuis une dizaine d'années dans les placettes du Centre National de la Recherche en France dans la région méditerranéenne, dans les cédraies du Rif, du Moyen Atlas, au Maroc et dans les cédraies des Aurès et de l'Atlas de Blida en Algérie. Des classes de croissance ont été élaborées soit à partir d'analyse de tiges dominantes (France), soit à partir de placettes temporaires réparties convenablement sur l' ensemble des âges des peuplements (Rif, Moyen Atlas oriental).Les tables de production à sylviculture moyenne sont construites pour les cédraies (Toth 1973,YI Byoung 1976, M'Hirit 1982, El Kasri 1982, Ben Embarek 1985, Ziat 1986, Nedjahi 1987).

Tableau 5: Classes de croissance du cèdre de l'Atlas (Hauteur dominante à 100 ans)

classe de croissance	Rif (M'HIRIT 1982	Moyen Atlas tabulaire (EZZAHIRI 1989)	Moyen Atlas oriental (ZIAT 1986)	Atlas de Blida (NEDJAHI 1987)	France (sud) (TOTH 1973)
I (très fertile)	27	36	30	28	32,5
II(fertile)	25	30	25	24	26,5
III(fertilité moyenne)	22	24	21	19	20,5
IV (fertilité moyenne)	19	18	17	14	13
V (pauvre)	12	-	12	-	-

Les classes de croissances extrêmes sont comparables pour l'ensemble des cédraies.Néanmoins en dehors de son aire le cèdre semble plus performant.Les accroissements du cèdre sont présentes dans le tableau ci-après:

Tableau 6: Accroissement du cédre de l'Atlas (m3/ha/an)

classe de croissance	Rif	Moyen Atlas oriental	Aurès	France (sud)
I	8,30	7,42	3,48	12,8
II	6,52	4,65	-	-
III	5,31	3,18	1,82	-
IV	4,20	2,02	-	7,2
V	3,5	0,95	0,78	-

Tarifs de cubage et productivité

Plusieurs types de tarifs sont construits dans les cédraies nord africaines et dans les plantations de cèdre en France , soit à l'occasion de l'établissement des aménagements de forêt,soit pour des études générales prospectives ou prédictives de production (Anon 1978, M'Hirit et al. 1983, 1984, 1985, Postaire et al. 1985).

TARIFS DU RIF MAROCAIN

Dans le Rif marocain , les tarifs de cubage ont fait l'objet d'étude approfondies faisant intervenir la forme des arbres comme critères de stratification de l'échantillon d'arbres utilisés pour leur construction. Les modèles d'équation utilisés sont de la forme ($v = b_0 + b_1 d^2$) pour les tarifs à une entrée et d' un polynôme du 3ème degré avec ses neufs termes pour les tarifs à deux entrées.

Tableau 2 : Tarifs de cubage du Rif (O. M'Hirit 1982)

type	équation - tarifs	cœfficient de variation	effectif
toute la cédraie	$v = 0,101 + 0,320\ d^2$ $v = 0,139 + 1,472\ d - 0,008h + 0,246d^2h$	43 30	356 356
massifs du Rif occi-dental	$v = 0,324 + 7,446\ d^2$ $v = 0,334 + 1,351\ d + 0,264\ d^2h$	33 30	225 225
massif du Rif central et oriental	$v = -0,159 + 7,507\ d^2$ $v = -0,007 - 1,884\ d + 4,757d^2 + 0,113dh + 0,094\ d^2h$	31 17	331 331

$v(m^3)$ volume bois fort; d(m) diamètre à 1,80m; h(m) hauteur de la découpe

TARIF DU MOYEN ATLAS CENTRAL

L'échantillon d'arbre utilisé pour la construction des tarifs est stratifié par rapport à deux critères : l'aspect de la cime (cime du type flèche et cime de type table) et au subtratum lithologique (dolomies et calcaire d'une part, grès et dolérites d'autre part). La formule utilisée est de la forme : $v = a\ c^b h^c$. Les analyses de régression et de la variance concluent à la nécessité de distinguer les arbres selon l'aspect de la cime, et de distinguer entre substrats pour les arbres de type table.

Tableau 3: Tarifs de cubage du Moyen Atlas central

type	équation - tarifs	cœfficient de variation	effectif
tous substrats et tous types	In(v)= -2,2839 + 1,9636 In(c) + 0,7463 In(h)	4,4 %	573
tous substrats-cime flèche	In(v)= -2,6089 + 1,60791 In(c) + 0,9078 In(h)	9	270
dolomie et calcaire-cime table	In(v)= -1,9689 + 2,0065 In(c) + 0,6411 In(h)	1,5	194
grès et dolérites, table	In(v)= -2,5598 + 1,9168 In(c) + 0,8611 In(h)	1,9	109

v(m) volume commercial; c(m) circonférence à 1,30m; h(m) hauteur bois fort

Tarifs du Moyen Atlas oriental

Dans le Moyen Atlas oriental les tarifs à deux entrées ont été établis pour l'ensemble des forêts en utilisant la relation $v = bo + b_1 c^2h$. Les tarifs à une entrée sont établis par contre, par forêt et par type de peuplement en utilisant la relation $v = bo\ c^{b_1}$.

Tableau 4: Tarifs de cubage du Moyen Atlas oriental

forêt	peuplement	équations tarifs	cœfficient de variation	effectif
Taffert	cédraie vieille et adulte	$v= 0,851\ c^{2,362}$	2,3	-
	cédraie jeune et mixte	$v= 0,602\ c^{2,520}$	2,3	-
Tamtroucht et Tizi Aîni	cédraie vieille et adulte	$v= 0,766\ c^{2,519}$	2,9	-
	cédraie jeune et mixte	$v= 0,521\ c^{2,546}$	2,8	-
toute la cédraie		$v= 0,00024 + 0,03887c^2h$	24,1	279

La production totale des cédraies du Rif est importante comparativement aux autres types de cédraies.Elle est nettement plus importante dans les plantations artificielles françaises . Les modèles de croissance sont établis pour le Rif et le Moyen Atlas oriental et des modèles de sylviculture sont proposés.

S y l v i c u l t u r e e t a m e n a g e m e n t

Régénération du cèdre

La régénération du cèdre a donné lieu de nombreuses investigations, plus particulièrement , au Maroc pour les forêts naturelles et en France pour les reboisements. Le cycle complet de production des graines chez le cèdre jusqu'à leur dissémination dure,en général,trois ans,il se prolonge pendant quatre ans dans certaines conditions . Il peut se résumer comme suit , la première année il y a apparition des inflorescences, floraisons et pollinisation;la deuxième année, il y a fécondation des ovules par les graines de pollen et croissance des cônes ; la troisième année se produit la maturation des cônes et leur désarticulation qui aboutit à la dissémination des graines.La désarticulation peut se prolonger une quatrième année . La qualité et la quantité des graines sont fonction des conditions climatiques qui influent sur la pollinisation,la fécondation et la croissance des cônes (Toth 1978, 1979, 1980).

Les graines de cèdre ne sont pas photosensibles,elles germent indifféremment à la lumière et à l'obscurité. Ceci résulte de la présence dans l'embryon d'une chromoprotéine (le phytochrome).Elles possèdent aussi une grande rapidité germinative en hiver et au début du printemps en raison de leur réhydratation rapide et leur résistance à la dessication . Mais pour germer la graine à besoin de subir l'action du froid pendant quelques temps, ce qui permet la levée de la dormance et la conservation. Le seuil minimal de germination, pour des graines hydratées se situe entre +2°C et +4°C . Ainsi la germination des graines de cèdre et l' installation des plantules peut se faire quand la température est de l'ordre de +4°C ou audessus (Zaki 1968, Abourouh 1983).

La fructification apparaît comme le facteur prépondérant de la distribution spaciale de la régénération naturelle. De même la réponse de la régénération aux conditions de recouvrement montre presque toujours le rôle favorable des recouvrements moyens par opposition aux recouvrments extrêmes. La période de récolte se situe entre juillet et décembre.

Notons qu'un kg de bonnes graines est fourni par 100 à 125 cônes et donne 13.000 graines . Le poids moyen de 100 g est de l'ordre de 7 g . La récolte est faite, sur les cônes de couleur brune dont les écailles supérieures commencent à s'entrouvrir sous l'effet de la chaleur et de l'humidité . Le décorticage des cônes mûrs est , en principe, facile, sinon les cônes sont trempés pendant 48 heures dans l'eau; les cônes de cèdre ayant la particularité de s'ouvrir sous l'action de l'humidité.Les graines sont

ensuite désaillées,séchées et conservées dans des chambres froides si leur utilisation doit être faite dans un délai supérieur à six mois (Demoyen 1964, Phipps et al. 1977, George 1980).

La graine de cèdre conserve sa faculté germinative plusieurs années lorsqu'elle est stockée dans des récipients hermétiquement clos et lorsque son taux d'humidité ne dépasse pas 10%. Néanmoins,avant le semis, un prétraitement au froid humide (+ 4°C) ou une stratification garantissent une meilleure levée . Des recherches récentes sur la levée de la dormance et de la germination ont conclu à la stratification à(+4°C)ainsi qu'un traitement d'une heure à l'eau oxygénée à 35 % . Les plants produits en pépinière, destinés à la plantation, ont en général une saison de végétation, rarement deux (Prax 1961, Lepoutre 1963,Lepoutre et al. 1963,1964,Clauzel 1976, Cousin et al. 1976).

Traitement et aménagement des cédraies

Le cèdre de l'Atlas est actuellement la seule essence en Afrique du Nord dont la sylviculture à fait l' objet d' application sur une grande échelle en raison de sa régénération par semences et des produits obtenus (bois d'œuvre en majorité). Le mode de régénération et le produit principal imposent des modes de traitement et des méthodes d'aménagement en futaie : la futaie régulière et la futaie jardinée (Jansen 1971, Anon 1971, 1978, 1980).

Aménagement en futaie régulière

Le mode de traitement en futaie régulière est le plus utilisé en raison de la qualité des bois produits et de la facilité de réglementation du parcours.La conduite des peuplements est basée sur la régénération par la méthode des coupes progressives et l'éducation et l'amélioration des peuplements au moyen d'éclaircies périodiques.

Dans le cas le plus général deux méthodes d'aménagement sont appliquées:la méthode du groupe de régénération strict et la méthode du groupe de régénération élargi. La forêt est divisée en 3 ou 4 groupes de parcelles correspondant chacun à un stade de développement du peuplement ou classe d'âge et donc à un type d'intervention approprié: le groupe de régénération , le groupe de préparation , le groupe d'amélioration et le groupe d'attente. Les deux méthodes d'aménagement ne diffèrent que dans la relation entre le groupe de régénération et la surface à régénérer pendant la durée de l'aménagement. Dans la méthode du groupe de régénération strict les parcelles du groupe de régénération seront totalement régénérées à l'issue de l'aménagement. Dans l'autre méthode une ou plusieurs parcelles ne seront pas totalement régénérées à la fin de l'aménagement.

Aménagement en futaie jardinée

Jusqu'à présent le jardinage n'a pas été utilisé sur une grande échelle, du fait des difficultés de réglementation de la mise en défens. Il est pourtant bien adapté aux caractéristiques de la cédraie : difficultés de régénération, danger des incendies. En plus, les études entreprises sur l'équilibre et le dynamisme actuel de la cédraie montrent que le traitement en futaie jardinée, conservant un couvert permanent sur toute la surface, est propre à préserver la pérennité de la forêt.

Dans la cédraie deux types de jardinage sont utilisés : *le jardinage intensif* et *le jardinage extensif*. Dans le premier type, qui correspond à une futaie jardinée par pied ou par bouquet, la coupe de jardinage est polyvalente. (régénération et amélioration) fréquente (rotation = 7 ans) et légère. Le jardinage extensif correspond aux futaies jardinées par parquet; l'âge d'exploitabilité est sans intérêt (arbres âgés en général), la possibilité est par contenance tandis que la rotation est de l'ordre de 20 ans. Dans ce type de peuplement la majorité des parcelles est partiellement en régénération mais celle-ci est concentrée dans l'espace. Les parcelles peuvent être classées en ensembles différents, certaines pouvant être parcourues par des coupes de régénération, alors que d'autres sont parcourues par des opérations d'amélioration. Le jardinage extensif est appliqué particulièrement dans les cédraies marginales d'altitude où les conditions écologiques, topographiques, les conditions de régénération et de vidange des produits sont difficiles.

Contraintes de la sylviculture du cèdre : le parcours

Le parcours en forêt, en Afrique du Nord, fait partie des droits d'usage de la forêt. Ainsi, la réglementation pastorale est une constante de la sylviculture dans ces forêts; elle varie suivant le mode de traitement et conditionne la division de la forêt et la constitution des groupes de régénération.

En futaie régulière le groupe de régénération est interdit au parcours durant la durée d'application de l'aménagement de la série. La surface de ce groupe ne doit pas dépasser celle admise par le taux de mise en défens prévu dans la législation forestière: soit 1/5 de la série. Les considérations relatives à la réglementation du parcours interviennent également dans la fixation de la durée de l'application de l'aménagement. Aussi le choix des parcelles qui composent le groupe de régénération doit-il en tenir compte. Et l'on peut être amené à fractionner, ce groupe en plusieurs secteurs ayant des usages différents.

En futaie jardinée la réglementation de la mise en défens est probablement la raison principale pour laquelle ce traitement n'est pas plus répandu dans les cédraies. Dans certaines conditions la mise en défens des parcelles n'apparaît pas comme absolument obligatoire : parcours peu intense, présence d'un sous-bois ou d'un sous-étage bas qui assure une protection au semis. Ce cas est très rare en raison de l'importance du parcours dans les cédraies. Dans d'autres cas une mise en défens partielle

est appliquée. Les parcelles les plus sensibles, en particulier celles où des compléments de régénération sont effectués(semis ou plantations) sont interdites aux troupeaux durant le temps jugé nécessaire. Dans ce cas, il faut admettre que d' autres parcelles passent en coupe de jardinage sans mise en défens ultérieure.

CONCLUSION

Le cèdre de l'Atlas , espèce montagnarde , forme spontanément sept blocs distincts dans les montagnes de l'Afrique du nord,au Maroc (130.000 ha) et en Algérie (40.000 ha) . Il se développe essentiellement dans les variantes froides des ambiances climatiques subhumides,humide et perhumides. Son optimum bioclimatique correspond à l'étage montagnard méditerranéen entre 1600 m et 2000 m. L'originalité phyto - édaphique du cèdre de l'Atlas réside dans la diversité de ses communautés végétales, quoique intégrées dans l'ordre des *Quercetalia ilicis* et des *Querco Cedretalia atlanticae*, dans sa rusticité et son indifférence à la nature chimique des substratum lithologique.

Dans les cédraies naturelles,de nombreuses études relatives à la régénération et à la conduite des peuplements ont été entreprises au Maroc et en Algérie et dans les pays d'introduction , plus particulièrement en France et en Italie . Les études de la productivité du cèdre ont abouti à la construction de nombreux tarifs de cubage et de classe de croissance dans les différents types de cédraies, voire des modèles de croissance et de tables de production,plus particulièrement dans le Rif et le Moyen Atlas oriental.Cinq classes de croissances sont définies par l'ensemble des cédraies ; le "site index" (hauteur dominante à 100 ans) varie entre 12 m et 36 m , tandis que l'accroissement correspondant varie de 0,95 m^3/ha/an à 8,30 m^3/ha/an en peuplement naturel et peut atteindre 12 m^3 /ha /an en peuplement artificiel hors de son aire.

Les mécanismes de régénération du cèdre ont donné lieu à de nombreuses investigations qui ont permis d' appréhender les cycles de production des graines et les phases de régénération . Le mode de régénération et le produit principal du cèdre(bois d'œuvre)imposent des modes de traitements et des méthodes d'aménagement en futaie, la futaie régulière et la futaie jardinée. Dans le cas général deux méthodes d'aménagement sont appliquées dans les futaies de cèdre: la méthode du groupe de régénération strict et la méthode du groupe de régénération élargie. En futaie jardinée, le jardinage intensif est appliquée en futaie en équilibre et le jardinage extensif dans les cédraies marginales.Ces modes de traitement et d'aménagement sont nuancées en raison du parcours dans les forêts du cèdre qui fait partie des droits d'usage de la forêt en Afrique du Nord.

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WATER REQUIREMENT FOR OPTIMUM GROWTH OF EUCALYPTUS CAMALDULENSIS, SALMALIA MALABARICA, MORUS ALBA AND POPLAR CLONES

Mahmood Iqbal Sheikh, 150-A, Scotch Corner,
Upper Mall Scheme, Lahore (Pakistan)

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1. Introduction

Irrigated plantations in Pakistan which cover an area of 0.23 million hectares are quite unique in so far man made forests of the world are concerned. Use of canal water for growing trees was started more than 120 years back. First-ever irrigated plantation of the world was laid out in 1865 at Changa Manga in the Punjab. After that, several plantations have been raised in different parts of the country varying in size from a lowly 300 ha to about 8000 ha each. The principal species raised in these plantations to meet the requirement of fuelwood and timber include Dalbergia sissoo, Morus alba, Acacia nilotica, Salmalia malabarica and of late Eucalyptus camaldulensis and different clones of poplars. Inspite of such a long history of raising irrigated plantations, very few studies have been made to find out the optimum dose of water for the best rate of growth of a particular tree.

Nevertheless canal water is a precious commodity in Pakistan. But for the availability of the flow irrigation supplied through a system of dam reservoirs, canals and distributories, which has made the Indus Basin one of the

most productive regions of the world, the country would have very well remained a desert. With the precarious water supply position from the rivers and in view of the increased requirement of water for expanding agriculture, it became highly imperative to lay out some scientific studies to find out the effect of various deltas and frequencies on the rate of growth of four important species namely, Dalbergia sissoo, Eucalyptus camaldulensis, Morus alba and 4 clones of Populus deltoides. in Chichawatni Irrigated plantation.

2. Past work

The importance of conservation of irrigation water and the need to find optimum water requirement of the species raised in irrigated plantations has not received the attention it rightfully deserves. Qadri (1) conducted experiments on season of irrigation in relation to growth of Acacia nilotica, Dalbergia sissoo, Salmalia malabarica and Populus euphratica. These experiments revealed that there was no appreciable difference in the growth of these species if these are not irrigated in the month of March, April or early May. Hence in his view there was a possibility of saving considerable quantity of water by not irrigating the crops in these months. Qadri (2) conducted some experiments on Acacia nilotica in Hyderabad and found that the effect of surface irrigation during the establishment period of the crop

was more pronounced than in the case of already established plantations.

An experiment was laid out in 1958 in Pirawala to determine the rate of growth of Dalbergia sissoo under different deltas, frequencies and methods of irrigation. The experiment was laid out under a split plot design to consider the following variables:

- Intensities of irrigation using 0.45; 0.9; 1.35; 1.8; and 2.25 meter delta per season.
- Frequencies of irrigation: Fortnightly; three weekly; and monthly.
- Methods of irrigation - Trenching and Flooding.

Sheikh, et.al.(3) conducted first thinning in this experiment when the crop was 5 years old. The data indicated that trench system of irrigation produced more growing stock; the frequency of irrigation did not have much effect; and growth was directly proportional to the quantity of water given.

Sheikh (4) re-assessed the study when ten years old. It indicated that amongst the three variable put to test, quantity of the water applied was the most important factor. It was further indicated that increase in growth was more pronounced when there was a comparative increase in delta from 0.9 - 1.3 meters; that the method of irrigation did

not have any effect; and that fortnightly irrigation would give more volume per unit area. Another significant indication of note was that if irrigation was properly regulated it was quite possible to get atleast 75 m^3 of wood per ha on the average from the second thinning when the plantation was about 10 years old. This quantity is almost three times the wood which is usually available from irrigated plantations at the time of second thinnings.

Sheikh (5) in July, 1981 started a study in the Pakistan Forest Institute campus to find out the effect of frequency of irrigation with canal water on the rate of growth of four species, under five watering frequencies viz; weekly, 2 weekly, 3 weekly, 4 weekly and no irrigation. The data on survival and growth recorded in April, 1983 are presented in tables 1 and 2.

There was no significant difference between the survival of plants under different irrigations. However, the survival of Robinia pseudoacacia decreased with the decrease in water supply. This showed that Robinia pseudoacacia will not grow well without irrigation at Peshawar.

There was an appreciable difference of height between different species and also under various irrigation frequencies. Leucaena leucocephala out-grew all other species recording double the height of the others.

There was also significant difference between the heights of plants in different irrigation frequencies. The weekly irrigation gave more height than all other irrigation treatments. This was specially true in case of iple-iple which had a much greater average height in weekly irrigations than all others.

Table 1. Survival out of 28 plants

Irrigation	Leucaena leucocephala	Robinia pseudoacacia	Ceratonia siliqua	Tecoma undulata
Weekly	28	23	25	18
2-weekly	28	18	25	25
3-weekly	27	19	25	27
4-weekly	25	19	26	28
No irrigation	28	6	22	28
Average for the species	27	17	25	25

Table 2. Average height (m) after two years

Irrigation	Leucaena leucocephala	Robinia pseudoacacia	Ceratonia siliqua	Tecoma undulata
Weekly	3.7	1.1	1.4	1.0
2-weekly	3.2	1.0	1.2	1.6
3-weekly	3.2	0.8	1.2	1.6
4-weekly	2.9	0.9	1.2	1.5
No irrigation	2.6	0.8	1.1	1.4
Average for the species	3.1	0.9	1.2	1.4

The total biomass production per tree per year of iple-iple in weekly irrigation treatments was 7.8 kg. which was 6 times that of control (1.27 kg.) and more than double of any other irrigation treatment (3.25 kg. in 2-weekly irrigation, 2.25 kg. in 3-weekly irrigation and 2.09 kg. in 4-weekly irrigation). Tecoma undulata an arid zone species, however, did not show difference due to irrigation frequencies, indicating that it can be easily grown without irrigation in Peshawar zone.

3. The site and its environment

- The plantation

Chichawatni plantation was started in 1913 by clearing the virgin land occupied by a wide variety of xerophytic vegetation such as Tamarix articulata (Frash), Prosopis cineraria (Jand), Salvadora oleoides (Van), Capparis aphylla (Karir) and some shrubs as Zizyphus numularia (Malah), Calotropis procera (Ak) and grasses like Saccharum munja (Kana), Desmostachya bipinnata (Dab), Panicum antidotale (Gharam). Dalbergia sissoo (Shisham) was naturally the first choice to start planting using seed instead of present practice of using root-shoot cuttings which is a later development. Initially, shisham was the only species which was seeded on a large scale. Morus alba came naturally under the shade of 4-5 years old shisham crop through dropping of the starling. Artificial planting of mulberry was also undertaken to have the two-storeyed forest. Eucalyptus rudis was introduced in

twenties but its spread was restricted due to the attack of white ants and exorbitant cost on weedings. Eucalyptus camaldulensis known as E. rostrata at that time was also planted subsequently with reasonably good results but the problem of weeds persisted. The later introductions were Melia azedarach, acacia nilotica, Salmalia malabarica, Acacia modesta, Broussonetia papyrifera and even mesquite with the primary objectives to obtain a mixture and to stock the comparatively poor and uncommanded areas with hardy xerophytic species.

- Geology and soil

Geological formation is alluvium deposit by the rivers. The soil on the whole is a fine clayey loam with high moisture retaining capacity. The Soil Survey of Pakistan has divided the plantation soil into 4 categories according to its potential. These are; land with high economic potential with moderate economic potential; with low economic potential and with no economic potential at all.

- Rainfall

The average annual rainfall varies from 200-250 mm. Generally monsoons break early in July and most of the rain is received in July and August. Light, infrequent showers are there in winter also.

- Climate

The climate of the area is on the extremes. It is very hot in summer and cold in winter with frosty nights in

January and February. The maximum and minimum temperature ranges between 3°C - 43°C. Dust laden wind storms are experienced from July to September.

-Canal water supply

The plantation receives its irrigation from the Lower Bari Doab canal and the two forest distributories exclusively meant for the plantation. When the plantation was originally started the sub-soil water level was about 18 m. Generally, over a period of time with irrigation, now it ranges between 8-10 m in different parts. The irrigation season is from April to mid-October. Trench system of irrigation is in vogue.

4. Layout and design

A piece of land covering 7.7 ha which had remained under Dalbergia sissoo for about 50 years and had recently been clear felled was selected for this study in Chichawatni irrigated plantation. The roots were uprooted and the site levelled with tractor. Deep ploughing was also done to remove the root vestiges. A plot of 419.5 x 184 metres was marked. It was divided into requisite number of plots, roads and provided with water channels, flumes etc. Size of each individual plot was 30.5 x 30.5 metres. 2 metre apart trenches were dug and connected with the water courses for supply of water. There were 60 plots in all, one plot

carrying 256 trees. Each species was thus planted in 15 plots. Planting of Salmalia malabarica, Morus alba and Eucalyptus camaldulensis was done in August, 1977 while cuttings of four deltoides clones, viz 72/58, 4/64, 64/55, 90/60 were introduced subsequently in February, 1978. Random line planting of all the four clones was done in every plot allotting four lines to each clone.

5. Irrigation schedule

Following three deltas[1] with different depths of irrigation were prescribed.

Table 3. Details of deltas prescribed

Treatment	Depth of water given in one season	Depth of water given in one irrigation
D_1	0.90 m	7.50 cm
D_2	1.35 m	11.25 cm
D_3	1.80 m	15.00 cm

The treatments were replicated 5 times. Water supply was controlled with iron shutters. Masonery flumes were constructed at the mouth of each plot and a scale was painted on one side. The quantity of water to be delivered to each

Delta[1]: Depth of water delivered to one acre in one irrigation season.

plot was caliberated with the level of water on the scale with the time for which water was allowed to the plot through the flumes.. In all the three treatments, 12 irrigations were given in one season. Irrigation schedule is given in appendix-I.

6. Thinning of the crop

In order to remove congestion of the crop which was very apparent in three years due to initial close spacing, a number of thinnings had to be done. In 1981, the first thinning was carried out taking the following steps:

- DBH of all the standing trees of all the four species was recorded with basal areas against each.
- Each plot was then visited and trees required silviculturally to be thinned out in addition to dead, dying diseased, top broken or of defective stem form, were marked with white cross marks. The same trees were marked in the enumeration lists according to their serial numbers.
- Total basal area of standing trees in each plot and the basal area thinned out were calculated. Percentage of the thinned and retained trees with respect to both number of standing trees and their basal area were also calculated. The actual thinning was then carried out.

The same criteria were adopted for the subsequent two thinnings done in 1985 and 1987. Data on height and diameter were recorded since 1978 onwards and are given in appendix-II and figures 4 and 5.

In 1987, the study was finally evaluated and a very interesting picture of growth parameters such ad diameter, height and volume emerged. It is given in table-4 at page 12.

7. Analysis of data

The analysis of data recorded in 1987 gave the following results.

7.1 Diameter

There was significant difference at 5% level in diameter growth. The maximum diameter was gained by Salmalia malabarica followed by E. camaldulensis. Growth was nevertheless significantly low in both mulberry and poplars comparatively. It was indicated that higher the delta the better was the rate of growth. (Fig.1)

7.2 Height

Height growth was significantly different for each species. Maximum was recorded by E. camaldulensis followed by Simal, Poplars and Mulberry. This could, however, also be attributed to the genetic make up of a species for attaining

Table 4. Comparative growth study of four species under different depth of irrigation.

	Planted 8/77 E.camaldulensis			Planted 8/77 Mulberry			Planted 8/77 Simal			Planted 2/78 Poplar		
	D^1	D^2	D^3	D^1	D^2	D^3	D^1	D^2	D^3	D^1	D^2	D^3
1. DIAMETER Diameter (cm)	20.5	20.5	21.2	17.3	17.9	18.5	27.7	28.0	28.8	16.0	17.0	17.4
2. HEIGHT Height(m)	23.83	22.36	24.24	13.96	14.45	14.87	18.59	18.53	18.17	19.75	20.36	20.61
3. VOLUME Volume m^3/ hectare 1987												
- Thinning yield 1981	24.94	29.03	34.19	9.03	10.32	9.89	28.17	43.00	39.13	16.77	16.98	19.56
- Thinning yield 1985	36.49	33.22	39.90	9.25	9.28	9.09	41.91	41.72	39.75	11.39	12.37	10.90
- Thinning yield 1987	33.59	30.95	24.60	10.68	13.21	9.51	50.03	56.65	55.06	32.81	31.05	33.85
- Main crop 1987	160.85	179.64	196.72	90.19	90.41	101.01	321.70	328.54	338.02	131.02	158.68	164.37
Total:	255.87	272.84	295.41	119.15	123.22	129.50	441.81	449.91	471.96	191.99	219.08	228.68

better height under the given conditions. (Fig.2)

7.3 Volume

Volume growth of Salmalia malabarica was significantly better than eucalypts and poplar which was the second group in order of merit. The least volume was obtained from mulberry. Slower growth of mulberry is attributed to the fact that the partial over-head shade is required atleast in the early years of its growth which was not there. The species was also attacked by a root fungus resulting in the death of many trees. (Fig.3)

- Yield/hectare increased with increase in delta in case of all the species. However, when the quantity of watering was doubled the yield did not increase with the same proportion.
- Maximum effect of depth of water (D^1-D^2) was seen in the case of poplars. This is quite natural as the species does require more water for its normal growth. The species was third in yield because it is too far out of its habitat.

7.3.1 Performance of poplar clones

The four poplar clones used in the study, planted a year later than the other species, were analysed separately to find out their individual performance. Following conclusions were available.

- Irrespective of the depth of water given 1-69/55 gave the maximum volume production followed by 1-4/64, 1-72/58 and 1-90/60.

- Irrigation treatments D3 and D2 were mutually non-significant but significantly better than D1.

- Except in the case of 1-90/60 there was linear relationship between the delta delivered and the volume produced.

8. Recommendations

On the basis of the data available over a period of 10 years following recommendations are made to the foresters and farmers:

- *Salmalia malabarica* may be planted extensively, especially in the agroforestry systems.

- Response of *Populus deltoides* clone 69/55 in rather hot climatic conditions is very encouraging. This particular clone should be propagated to meet the requirements of a number of wood based industries such as paper and pulp, chip-board, ply-wood, packing cases etc.

- *Eucalyptus camaldulensis* has done very well even with the lowest quantity of water given to the crop. The species is thus well suited for massive planting on marginal lands in the low rainfall zones.

9. Acknowledgement

As principal investigator of the study I am deeply indebted to my colleagues in the Forestry Research Division of the Pakistan Forest Institute, Peshawar for assisting me in the lay out of the study, its annual measurements and the final analysis of data.

Appendix-II

Effect of three deltas (0.9, 1.35 and 1.80 m) on the diameter(cm) and height (m) of four species from 1978-1987.

Delta	1978	1979		1980		1981		1983		1985		1987	
	Ht.	Dia	Ht.	Dia	Ht.	Dia	Ht.	Dia	Ht.	Dia	Ht.	Dia	Ht.
Eucalyptus (planted August, 1977)													
1.	4.0	8.1	9.5	8.4	11.2	11.6	15.9	13.1	17.7	14.19	19.98	20.5	23.83
2.	3.6	7.9	9.2	8.6	11.3	11.7	13.4	13.4	17.7	15.2	20.28	20.5	22.36
3.	3.7	7.9	9.2	8.9	11.6	12.2	13.8	13.8	17.8	15.6	19.48	21.2	24.24
Mulberry (planted August, 1977)													
1.	2.2	5.6	5.2	6.3	5.6	9.9	8.1	11.3	9.5	14.0	12.20	17.3	13.96
2.	2.4	5.6	5.4	6.8	5.9	10.9	8.7	11.9	10.4	14.7	13.16	17.9	14.45
3.	2.4	5.6	5.2	6.5	5.7	10.6	8.8	12.4	11.2	15.1	12.86	18.5	14.87
Semal (planted August, 1977)													
1.	1.2	8.6	3.7	11.6	7.5	15.7	10.2	17.9	11.2	20.8	16.06	27.7	18.59
2.	1.4	9.4	4.2	12.0	7.5	16.7	10.5	19.0	11.6	21.8	16.82	28.0	18.53
3.	1.3	8.1	3.9	11.1	7.3	17.0	10.5	18.9	11.0	21.9	16.16	28.8	18.17
Poplar (planted February, 1978)													
1.	3.0	6.9	8.4	8.9	10.6	11.7	14.4	12.7	15.4	14.5	17.44	16.0	19.75
2.	2.8	7.1	8.4	8.9	10.7	11.0	14.4	13.1	15.7	14.7	18.18	17.0	20.76
3.	2.8	7.1	8.2	9.3	10.8	11.7	14.4	13.6	16.0	15.2	18.36	17.4	20.61

Fig. 1 DIAMETER (CM) ATTAINED BY FOUR SPECIES OVER A PERIOD OF TEN YEARS UNDER 3 DEPTH OF IRRIGATION

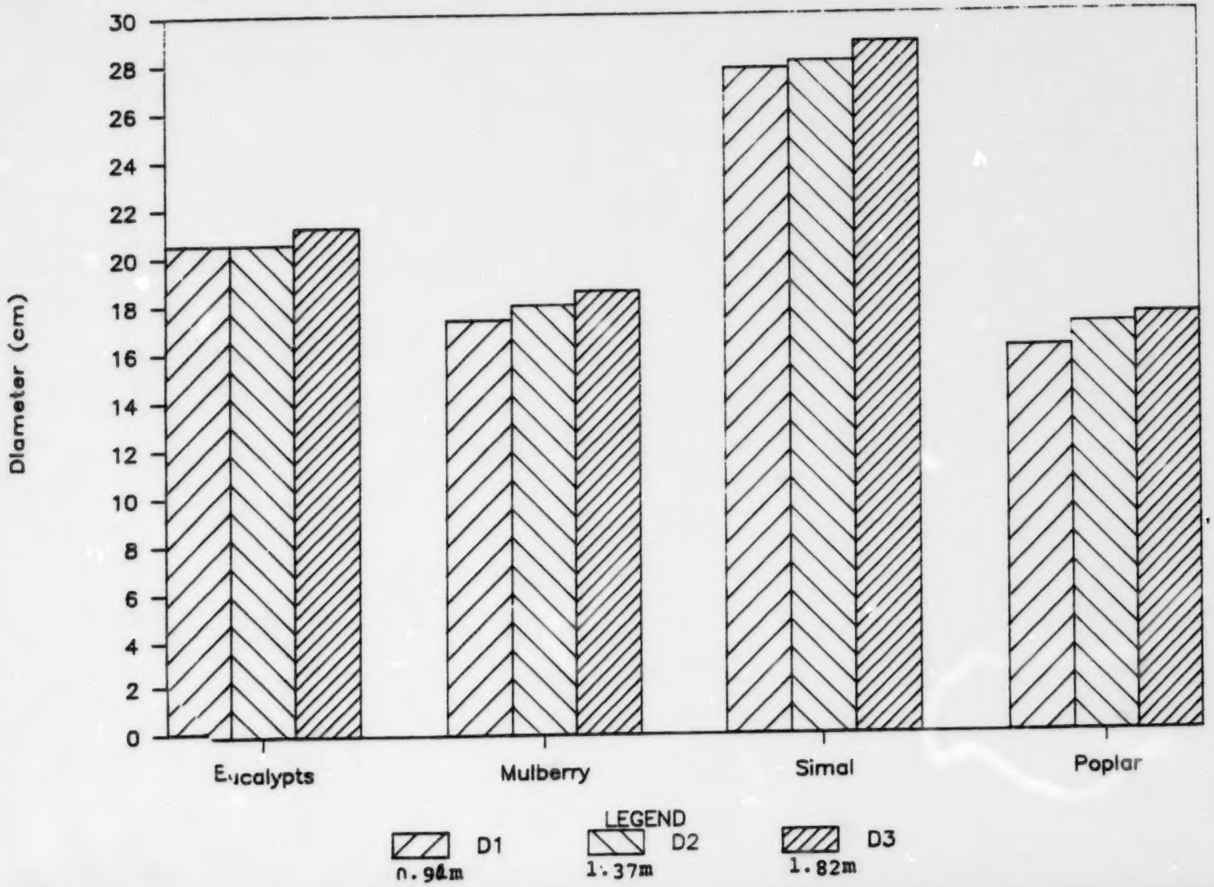


Fig. 2 HEIGHT(M) GAINED BY FOUR TREE SPECIES UNDER DIFFERENT DEPTHS OF IRRIGATION OVER A PERIOD OF 10 YEARS

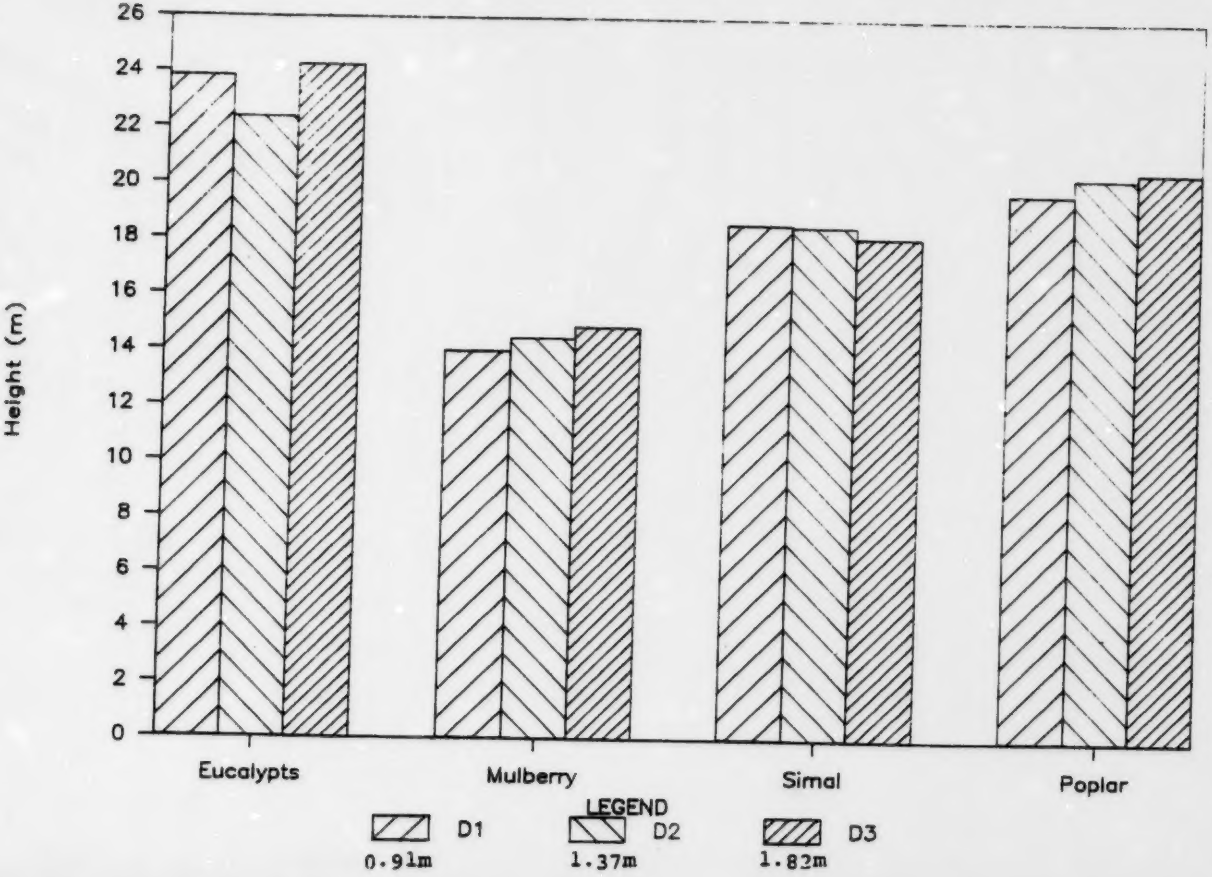


Fig. 3 VOLUME (m^3) AVAILABLE FROM 10 YEARS OLD CROP FROM FOUR SPECIES UNDER DIFFERENT DEPTHS OF IRRIGATION

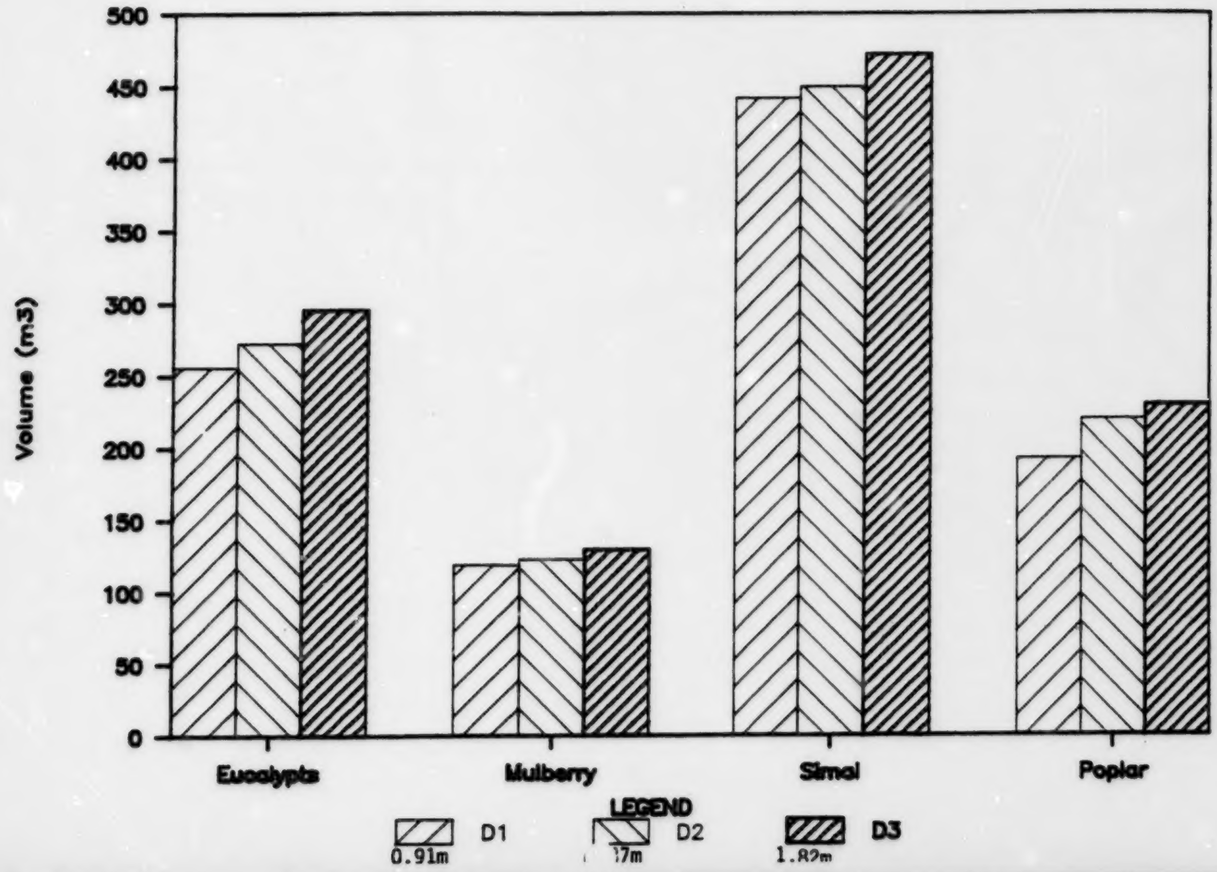


Fig. 4 Effect of three deltas (0.9, 1.35 and 1.80 cm)on the diameter (cm) of four species from 1979 - 1987.

(Eucalyptus,Mulberry, Semal-Planted August, 1977 and Poplar-Planted in Feb. 1978).

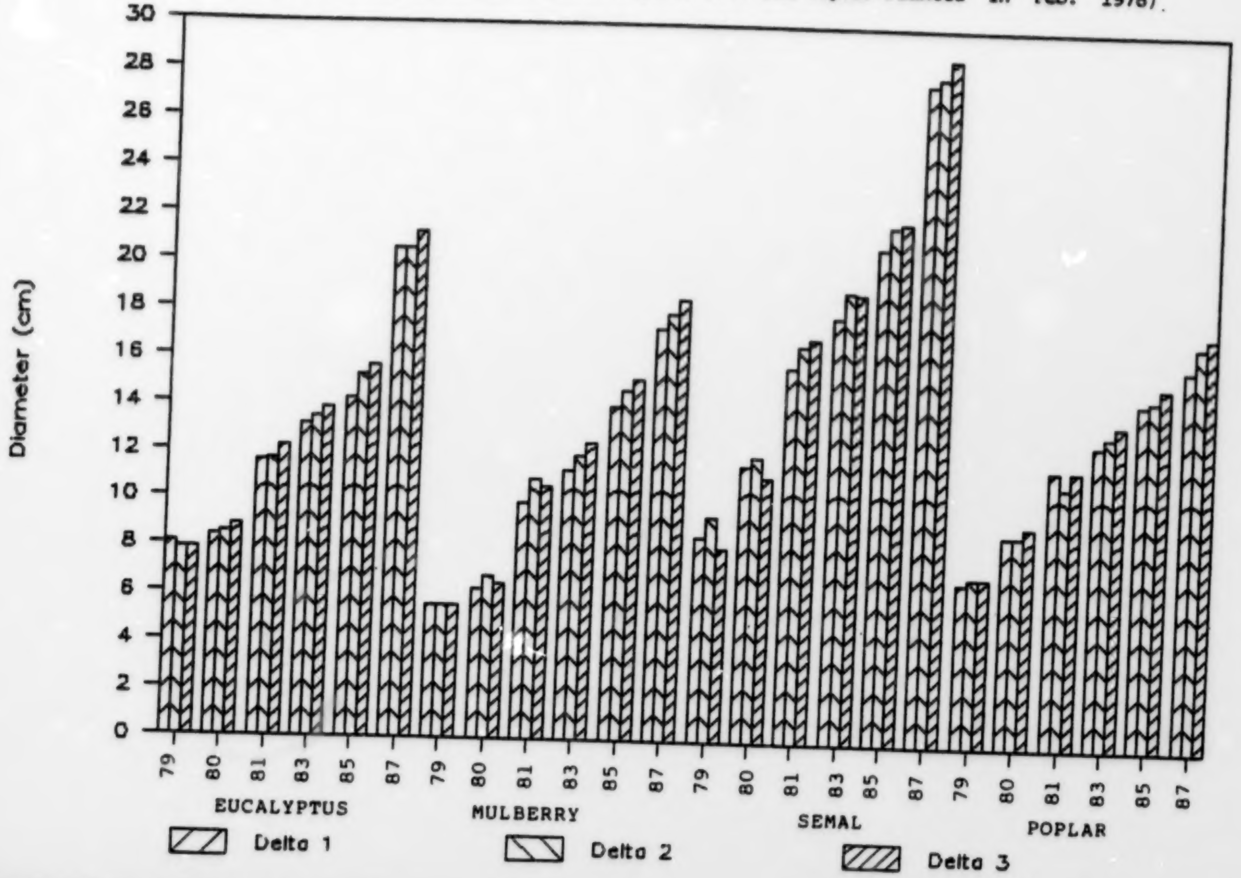
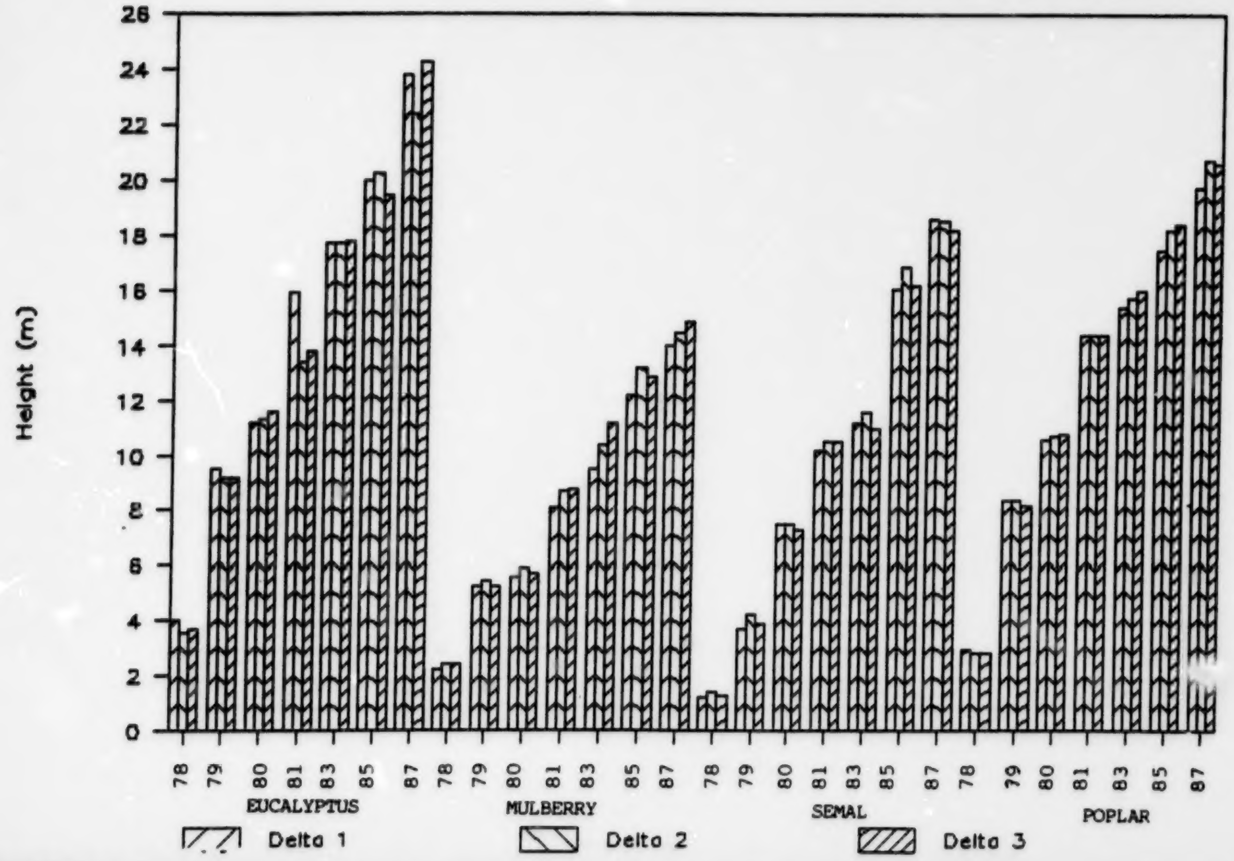


Fig.5 Effect of three deltas (0.9, 1.35 and 1.80 m) on the height (m) of four species from 1978 - 1987.

(Eucalyptus, Mulberry, Semal - Planted August, 1977 and Poplar - planted in Feb.1978)



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Dr. Helfried Oswald
Directeur de recherche
I.N.R.A. Station de sylviculture méditerranéenne
12, avenue A. Vivaldi
F-84000 Avignon
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NATIVE SPECIES FOR REFORESTATION AND LAND RESTORATION: A CASE STUDY FROM COSTA RICA

Rebecca Butterfield

Forestry Projects Manager
Organization for Tropical Studies
Apdo. 676
2050 San Pedro, Costa Rica

FDC: 232.11: (728.6)

SUMMARY

El desuso de árboles nativos en programas forestales es debido a la laguna de información biológica y silvicultural que existe sobre ellos. Sin embargo, algunas especies nativas crecen mejor que las exóticas y es posible manejarlas bajo condiciones de plantación. La Organización para Estudios Tropicales está manejando un proyecto de investigación en el noreste de Costa Rica sobre el potencial de especies poco conocidas para la reforestación y restauración de pastizales abandonados. Hay dos componentes del proyecto: 1)ensayos de hasta 100 especies de árboles, midiendo la sobrevivencia y el crecimiento inicial en pastos abandonados y 2)establecimiento de una plantación para investigar los efectos de árboles sobre las propiedades químicas y físicas del suelo a largo plazo. Se discute el diseño experimental y los resultados preliminares.

Keywords: Native species, screening trials, Costa Rica, reforestation

INTRODUCTION

The Humid Lowlands of Costa Rica

There are more than 1400 species of trees native to Costa Rica (Zamora 1989). Of these, at least 100 are of known commercial value, yet only one of them (*Cordia alliodora*) is grown in plantations in the Atlantic lowlands (DGF 1987, 1988). The incipient reforestation activity in the zone has focused on fast-growing exotics of low value such as *Pinus caribaea*, *Eucalyptus deglupta* and *Gmelina arborea*, thus ignoring the vast array of valuable hardwoods currently being logged from the forest. Although the sawmills depend almost exclusively on native species for raw material, these have been neglected in forestry programs due to the absence of management techniques.

Government financial incentives for reforestation require that species incorporated in reforestation programs must be approved by the Dirección General Forestal (DGF, Costa Rican Forest Service). Approval depends on the availability of analyzed data on tree growth under plantation conditions. Ironically, approved species such as *Pinus caribaea* and *Eucalyptus deglupta* with years of testing throughout the tropics have low market value in Costa Rica because of poor wood quality. The high quality native species, economically important to the wood processing industry, have not been approved due to lack of information on yields. Similiar situations exist in many other tropical countries.

There are several reasons why the promotion of native species in forestry programs should be considered. Increasingly, development projects focus on local resources and knowledge to improve land use. Native trees already have a local market, people know their various uses, and farmers are eager to plant them. Furthermore, native trees are often better adapted to local growing conditions, which may require a range of species to respond effectively to site variations.[1] If the tree population has not been overly reduced by indiscriminate cutting, local seed sources may exist. Secondarily, the promotion of native tree species conserves tropical species diversity and genetic resources while providing food and habitat to local wildlife.

The main obstacle to the use of native species in tropical forestry programs is the lack of basic biological, ecological and silvicultural information for their management. For some species, the taxonomic identification is still under discussion. For many, little is known about their reproductive biology. For the great majority, virtually no research has been conducted on their potential to be cultivated under plantation conditions. An additional barrier is the widespread, albeit erroneous, belief that tropical hardwoods are slow growing, require natural forest conditions, and are therefore unsuited for plantation forestry.

Research on Native Species

In 1985, the Organization for Tropical Studies (OTS) and the DGF established an experimental plantation at the La Selva Biological Station in northeastern Costa Rica, to test 13 native timber species. A paper presented at the 1989 meeting of the IUFRO Working Group S1.07-09 reported the results of this experiment (Espinoza and Butterfield 1989). Several native timber species, such as *Stryphnodendron excelsum* and *Vochysia hondurensis* have shown exceptional growth and form under plantation conditions, surpassing by far the growth of *Eucalyptus deglupta* and *Pinus caribaea*[2].

The encouraging results from the first plantation led to the project under discussion in this paper. In 1987 OTS in collaboration with the DGF,

1 In a degraded pasture site in Papua New Guinea the outstanding species were native although four of the twelve species tested were widely used exotics (Evans 1982, Lamb 1975).

2 The mean annual increment (MAI) in basal area was 5.9 m2/ha/yr for these two native species (Espinoza and Butterfield 1989). Other plantations in the Atlantic lowlands reported a basal area MAI for *Pinus caribaea* of 4.6 m2/ha/yr (an average of 4 plantations) and 2.7 m2/ha/yr for *Eucalyptus deglupta* (Camacho 1981).

undertook a three year project (TRIALS) to screen approximately 100 tree species for their potential in reforestation and rehabilitation of abandoned pastures. Approximately 80% of the species being tested are native to the region, with exotic species commonly used in reforestation programs included for comparative purposes. The project was divided into two major components: 1) species screeningtrials to test up to 100 tree species for survivorship and initial growth on abandoned pasture sites and 2) a long term plantation to monitor the effects of trees on chemical and physical properties of soils.

EXPERIMENTAL METHODS

S p e c i e s   S c r e e n i n g   T r i a l s

The species screening component required the development of an efficient experimental design that would allow replicated planting of a considerable number of species on a variety of sites at reasonable cost. The resulting design, using single tree plots which quickly identify the species with early promise, has proved cost-effective and efficient. It avoids the pitfalls of overplanting, in which large, costly plantations are created in the initial screening phase. However, the single tree plot design limits the life of the plantation to a few years due to inter-species competition. The most promising species identified in the screening trial (Phase I) will be planted in larger plantations for longer term monitoring (Phase II). This research sequence, species screening then species testing, has been outlined in Burley and Wood (1976).

Experimental design

The project uses a complete randomized block design with single tree plots. Each block, containing one tree of each species, is replicated 24 times per site. Blocks are contiguous with 3m x 3m spacing between all the trees. Block sizes vary with the number of species being outplanted. See Figure 1 for an example of the plantation layout.

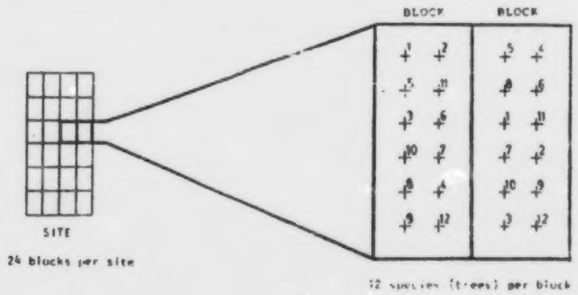

Figure 1: Experimental design: complete randomized blocks with single tree plots.

Although the ideal would have been to plant all 100 species at the same time, it was logistically impossible due to the lack of information on seed availability and germination for the native species. Seed collection was opportunistic. Once a minimum of eight species were ready for outplanting, the sites were prepared and the species planted in all the sites at once. Planting occurred only during the wet season from June through January.

The single tree plot design has several advantages: 1)it is a cost effective means to test a large number of species quickly, 2)border effects and the effects of one species dominating another are distributed randomly across the site and between species, 3)all the trees are measured since border effects are randomized, resulting in a 1:1 tree planted to tree measured ratio, and 4)in highly variable sites such as hills and tree-invaded pastures, the location of a species randomly throughout the site insures that it is tested OVER the site and helps to eliminate false results from micro-site variations. For example if in a single species block, two replicates of species A randomly fall at the base of the hill where erosion has deposited most of the top soil, species A may fare better than species B which was placed in a poorer microsite.

Some of the disadvantages of the single tree plot design are: 1)inter-species competition limits the life of the plantation to three years (at 3m spacing), 2)limited data collection time may not identify promising species which are initial slow growers, and 3)plantation layout and data management require more care as each individual tree must be labeled and randomly incorporated into the design.

Conventional designs using small single species blocks require more seedlings and land, thereby substantially increasing costs, with the advantage that data can be taken for a longer period of time. Table 1 presents a comparision of the different requirements in seedling production and plantation area for two experimental designs; the one described above and a standard design using single species plots of 5 x 5 trees (measuring the inside 3 x 3) with 4 replicates across 4 sites. Spacing is held constant for the two designs: 3m x 3m.

Table 1: Comparision of plantation area and seedling production for two experimental designs.

	P L A N T A T I O N			NURSERY/MEASURED	
	No. Trees/ species	Area/ species 100 sp.	Total area planted	No. Trees Produced 100 sp.	No. Trees Measured 100 sp.
1) Single Tree Plots 24 replicates x 4 sites	96	0.086 ha	8.6 ha	9,600	9,600
2) Single Species Plots (5x5) 4 replicates x 4 sites	400	0.36 ha	36.0 ha	40,000	14,400

Using a conventional design to test the same number of species would have required four times greater seedling production (and seed collecting) and over four times the area in plantation to measure 50% more trees.

Test sites

All the plantations were established at the La Selva Biological Station in Puerto Viejo, Sarapiquí, in the Atlantic lowlands of Costa Rica. The average annual temperature is 25.7 C. The station is situated between 35 and 150 m elevation (Hartshorn 1983). Average annual precipitation is 3840 mm with a dry season of 2-3 months (Feb.-April). The minimum monthly rainfall (152 mm) is in March and the maximum (481 mm) in July. According to the Holdridge Life Zone system, La Selva is within the Tropical Wet Forest Zone (Tosi 1969).

Test sites were chosen to reflect common soil and topographic types within the area (Sarapiquí). Emphasis was placed on marginal or degraded land unsuited for agriculture or long-term grazing: future targets for reforestation and land restoration programs.

The four sites are located on pasture or abandoned pasture land. Site one is flat, located on a weathered old alluvial terrace (Fluventic Dystropept) (Sancho and Mata 1987, Sollins et al. in press). The pasture area had been abandoned for approximately nine years. Average pH is 4.6. It is the (relatively) most fertile site of the four. Sites two, three, and four are located on hills with residual soils. The parent material is of volcanic origin. The soil is highy acidic, heavily leached with very low base saturation (30%). It has been classified as Ultisol although without well-developed clay skins it is closer to an Inceptisol (Sollins et al. in press). Sites two and three are located in a shrub and tree-invaded pasture that has been abandoned for nine years. Site two was cleared of all vegetation prior to planting, creating a full sun plantation. In site three the shrub and tree cover was maintained to lightly shade seedlings. Site four is in a recently abandoned pasture. It had been in pasture for more than 25 years and is considered to be most degraded of the four sites.

Basic nursery research

Due to the location of the project at an active tropical research center where the local flora has been under study for more than 30 years, candidate tree species for testing were easy to identify. However, basic information such as tree phenology and seed germination rates did not exist.

The project collected all the native seed used. Exotic seed was purchased through commercial suppliers. Information such as tree fruiting cycles, number of seeds per kilogram and fresh seed germination rates was obtained for each native species. The number of months each species spent in the nursery before outplanting was recorded. All seedlings were produced in nursery bags. No attempt was made to store seed; it was germinated fresh in order not to risk losing valuable supplies.

The data generated in nursery research provide valuable additional information for the selection of promising species for reforestation (González, in press). Species selection for Phase II will depend not only on growth factors but also on seed availability and germination rates in the nursery.

Tree/Site Interactions

One of the widely acclaimed benefits of reforestation is soil improvement. However, do all trees improve the soil in which they are growing? Do some species degrade the soil while others help to rebuild it? If trees are eventually to be harvested, what is the long term impact on the soil of several rotations of tree crops? The objective of this component was to collect the baseline soil information (pre-planting soil chemical and physical properties), and establish a long term plantation of promising timber species. Future researchers would be given access to the data and plantation for related studies on tree/site interactions.

Experimental design: tree/site interactions

A complete randomized block design was used. Plots are 0.25 ha with 4 blocks or replicates. Eleven species were planted with one control or fallow plot incorporated into each block. The 12 ha plantation is located at the La Selva Biological Station on land that had been in pasture for over 25 years and is now being allowed to regenerate naturally.

Species were selected according to their hypothesized effects on the soil. Five nitrogen fixing and six non-nitrogen fixing tree species were chosen. Within these two catagories species were identified as high or low litterfall producers and deep or shallow rooted (affecting nutrient uptake). A range of each variable is represented in the nitrogen-fixing or non nitrogen-fixing groups. Species currently used in plantations such as Pinus caribaea, Gmelina arborea and Acacia mangium were planted as well as some promising native timber species. Table 2 lists the species and their characteristics. Permanent inventory plots have been established to monitor tree growth.

Baseline soil analysis included total nitrogen, total carbon, bulk density, soil acidity, exchangeable cations and cation exchange capacity, and extractable phosphorus. The 0.25 ha plots were divided into quadrants. Twenty soil extractions from 15 cm depth were collected and mixed for each quadrant.

Table 2: Species in the tree/site plantation and their soil-affecting characteristics

NITROGEN FIXING SPECIES	FAMILY	DEEP ROOTED	HIGH LITTERFALL
Acacia mangium	Mimosaceae	-	+
Inga edulis	Mimosaceae	-	++
Pentaclethra macroloba	Mimosaceae	-	-
Pithecellobium macradenium	Mimosaceae	?	-
Stryphnodendron excelsum	Mimosaceae	-	-
NON-NITROGEN FIXING SPECIES			
Gmelina arborea	Verbenaceae	-	+
Hyeronima oblonga	Euphorbiaceae	-	+
Pinus tecunumenii	Pinaceae	+	+
Virola koschnyi	Myristicaceae	+	-
Vochysia ferruginea	Vochysiaceae	-	+
Vochysia hondurensis	Vochysiaceae	+	+

RESULTS

Species Screening Trials

To date, 76 species are under evaluation at the four sites described above (Table 3). The oldest plantation is two years old and the youngest has just been established (December 1989). Data will be collected on all the plantations for a total of three years at which time the most promising species will be identified for species testing in larger plantations.

Table 3: Species tested in OTS/DGF screening trials.

Exotic Species Widely Tested in the Lowland Humid Tropics:

Scientific Name:	Family:	Scientific Name:	Family:	Scientific Name	Family
Araucaria hunsteinii	Araucariaceae	Eucalyptus saligna	Myrtaceae	Pinus tecunumanii	Pinaceae
Acacia mangium	Mimosaceae	Gmelina arborea	Verbenaceae	Tectona grandis	Verbenaceae
Erythrina poeppigiana	Papilionaceae	Hevea brasiliensis	Euphorbiaceae	Terminalia ivorensis	Combretaceae
Eucalyptus camaldulensis	Myrtaceae	Pinus caribaea var.		Terminalia superba	Combretaceae
Eucalyptus deglupta	Myrtaceae	hondurensis	Pinaceae		

Species Indigenous to the Region:

Scientific Name:	Family:	Scientific Name:	Family:	Scientific Name:	Family
Brosium lactecens	Moraceae	Inga coruscans	Mimosaceae	Pithecellobium macradenium	Mimosaceae
Calophyllum brasiliense	Guttiferae	Inga edulis	Mimosaceae	P. pedicellare	Mimosaceae
Carapa guianensis	Meliaceae	Inga longispica	Mimosaceae	Pouteria spp	Sapotaceae
Castilla elastica	Moraceae	Inga thibaudiana	Mimosaceae	Pterocarpus rohrii	Papilionaceae
Cedrela odorata	Meliaceae	Jacaranda copaia	Bignoniaceae	Rollinia microsepala	Annonaceae
Cordia alliodora	Boraginaceae	Lacmellea panamensis	Apocynaceae	Simarouba amara	Simaroubaceae
Cordia bicolor	Boraginaceae	Laetia procera	Flacourtiaceae	Stryphnodendron excelsum	Mimosaceae
Cordia megalantha	Boraginaceae	Lecythis ampla	Lecythidaceae	Terminalia amazonia	Combretaceae
Dalbergia tucurensis	Papilionaceae	Miconia multispicata	Melastomataceae	Virola koschyni	Myristicaceae
Dipteryx panamensis	Papilionaceae	Minquartia guianensis	Olacaceae	Vitex cooperi	Verbenaceae
Genipa americana	Rubiaceae	Nectandra kunthiana	Lauraceae	Vochysia ferruginea	Vochysiaceae
Goethalsia meiantha	Tiliaceae	Nectandra membranacea	Lauraceae	V. hondurensis	Vochysiaceae
Hampea appendiculata	Malvaceae	Ochroma lagopus	Bombacaceae	Zanthoxylum mayanum	Rutaceae
Hernandia didymanthera	Hernandiaceae	Ormosia macrocalyx	Papilionaceae		
Hyeronima oblonga	Euphorbiaceae	Otoba novogranatensis	Myristicaceae		
Ilex skutchii	Aquifoliaceae	Pentaclethra macroloba	Mimosaceae		

Species Native to other parts of Costa Rica:

Albizzia guachapele	Mimosaceae	Ocotea spp.	Lauraceae	Pithecellobium saman	Mimosaceae
Brosium utile	Moraceae	Dipterodendron costaricense			Sapindaceae
Dalbergia retusa	Papilionaceae	Ormosia spp.	Papilionaceae	Pseudobombax septenatum	Bombacaceae
Enterolobium ciclocarpum	Mimosaceae	Pithecellobium arboreum	Mimosaceae	Simarouba glauca	Simaroubaceae
Gliricidia sepium	Papilionaceae	P. pseudotamarindus	Mimosaceae		
Myroxylon balsamum	Papilionaceae				

Little Known Exotic Species:

Guazuma crinita	Sterculiaceae

Preliminary (one year) data were analyzed for 32 species. To demonstrate initial survivorship and growth, the total height for each species was summed by site. Species are ranked according to those sums in Tables 4-7. Some trees of each species did not have diameters at breast height (DBH), therefore, the median DBH is given to indicate initial diameter growth. For comparative purposes the screening trial data for the most widely used species for forestry projects in the Atlantic lowlands of Costa Rica have been included in the tables.

Table 4: Site 1: (old alluvial soil, flat, full sun) One year growth and survivorship for the ten best species (ranked according to the sum of their heights) and of the three species most widely used in regional forestry projects. 24 trees planted of each species.

SPECIES	ORIGIN	SURVIVORS	HEIGHT SUM (m)	DBH (MEDIAN) (cm)
Ten Best Species				
1. Eucalyptus deglupta	c	24	102.2	4.3
2. Eucalyptus camaldulensis	c	21	90.7	2.9
3. Terminalia ivorensis	c	23	84.7	3.6
4. Dalbergia tucurensis	a	23	70.1	2.0
5. Jacaranda copaia	a	24	60.0	3.6
6. Vitex cooperi	a	24	57.1	1.7
7. Hevea brasilensis	c	23	53.2	1.7
8. Eucalyptus saligna	c	20	51.5	2.0
9. Pinus tucunumanii	c	24	50.4	1.2
10. Inga edulis	a	23	44.9	1.4
Currently Used Species				
1. Eucalyptus deglupta		24	102.2	4.5
2. Pinus caribaea		24	44.1	1.1
3. Cordia alliodora		21	20.8	0.0

a. No. of species indigenous to the zone: 4
b. No. of species native to other parts of Costa Rica: 0
c. No. of exotic species: 6

Table 5: Site 2: (residual soil, hill, full sun) One year growth and survivorship of the ten best species (ranked according to the sum of their heights) and of the three species most widely used in regional forestry projects. 24 trees planted of each species.

SPECIES	ORIGIN	SURVIVORS	HEIGHT SUM (m)	DBH (MEDIAN) (cm)
Ten Best Species				
1. Ochroma lagopus	a	20	103.2	7.0
2. Dalbergia tucurensis	a	23	66.5	1.6
3. Inga edulis	a	24	54.8	2.1
4. Hevea brasilensis	c	24	53.4	1.5
5. Jacaranda copaia	a	19	50.5	4.0
6. Gliricidia sepium	a	22	47.5	1.0
7. Laetia procura	a	24	45.5	1.1
8. Enterolobium ciclocarpum	c	23	42.5	1.0
9. Rollinia microsepala	a	20	38.4	1.4
10. Erythrina poeppigiana	b	23	37.6	1.4

Table 5 continued...

	SURVIVORS	HEIGHT SUM (m)	DBH (MEDIAN) (cm)
Currently Used Species			
1. Eucalyptus deglupta	10	30.2	1.9
2. Pinus caribaea	20	28.3	0.0
3. Cordia alliodora	22	22.9	0.0

a. No. of species indigenous to the zone: 6
b. No. of species native to other parts of Costa Rica: 2
c. No. of exotic species: 2

Table 6: Site 3 (residual soil, hilly, light shade) One year growth and survivorship of the ten best species (ranked according to the sum of their heights) and of the three species most widely used in regional forestry projects. 24 trees planted of each species.

SPECIES	ORIGIN	SURVIVORS	HEIGHT SUM (m)	DBH (MEDIAN) (cm)
Ten Best Species				
1. Ochroma lagopus	a	22	107.0	6.4
2. Dalbergia tucurensis	a	22	64.4	1.5
3. Jacaranda copaia	a	21	62.7	4.1
4. Hevea brasilensis	c	22	58.7	1.5
5. Rollinia microsepala	a	21	55.2	2.1
6. Laetia procura	a	23	46.1	1.3
7. Inga edulis	a	23	45.0	1.2
8. Eucalyptus deglupta	c	14	43.5	1.6
9. Lacmellea panamensis	a	20	43.2	1.0
10. Enterolobium ciclocarpum	b	22	40.5	0.4
Currently Used Species				
1. Eucalyptus deglupta		14	43.5	1.6
2. Pinus caribaea		20	24.3	0.0
3. Cordia alliodora		21	12.9	0.0

a. No. of species indigenous to the zone: 7
b. No. of species native to other parts of Costa Rica: 1
c. No. of exotic species: 2

Table 7: Site 4 (residual soil, hilly, degraded, full sun) One year growth and survivorship of the ten best species (ranked according to the sum of their heights) and of the three species most widely used in regional forestry projects. 24 trees planted of each species.

SPECIES	ORIGIN	SURVIVORS	HEIGHT SUM (m)	DBH (MEDIAN) (cm)
Ten Best Species				
1. Dalbergia tucurensis	a	24	77.2	2.1
2. Gliricidia sepium	b	24	50.1	0.8
3. Inga edulis	a	24	47.3	1.6
4. Enterolobium ciclocarpum	b	24	41.2	0.8
5. Pinus tucunumanii	c	24	38.0	0.6
6. Eucalyptus camaludensis	c	16	34.2	0.6
7. Vochysia hondurensis	a	24	33.3	0.0
8. Jacaranda copaia	a	23	32.7	0.0
9. Pinus caribaea	c	24	31.7	0.0
10. Pithecellobium saman	b	24	28.0	0.0

Table 7 continued...

Currently Used Species	SURVIVORS	HEIGHT SUM (m)	DBH (MEDIAN) (cm)
1. Pinus caribaea	24	31.7	0.0
2. Eucalyptus deglupta	15	21.9	0.0
3. Cordia alliodora	21	16.9	0.0

a. No. of species indigenous to the zone: 4
b. No. of species native to other parts of Costa Rica: 3
c. No. of exotic species: 3

Although these are preliminary data, they suggest that many native species have the potential to out-perform some of the exotics currently being used in plantations. Similiar results were obtained in a related experiment at three years of age (Espinoza and Butterfield 1989). Small changes in soil or site type can also influence which species are best adapted even within a small geographic area. A review of the ten best species for each site shows that site 1 and site 4 have only four species in common. The native species tended to do better on the less favorable sites. These specific results are, of course, not directly applicable to other areas. The general finding, however, indicates the value of native species research to find the best combination of species for local or regional forestry programs and the need to work with a wide variety of species to optimize growth on diverse microsites.

The end use of the trees will influence which species are considered the most promising and how tree growth and survival data are analyzed. For example, if gross wood biomass production is the goal then standard growth measurements can be used. However, a comprehensive analysis might include wood value; balancing rapid growth and low value wood against slow-growing but high quality trees. The wildlife value of the species might also enter the equation with weight given to those species that are important to wild game or endangered species such as the great green macaw. Species with slow growth and/or poor form might still be acceptable to local farmers who wish to inter-plant a few trees with crops. For example, Dalbergia tucurensis has acceptable growth but a heavily inclined or slanted form. The wood, however, is highly valuable and it may be worthwhile for farmers to plant several dozen trees around the dooryard garden.

Tree/Site Interactions

Baseline (pre-planting) soil samples have been analyzed. Preliminary information from older plantations at La Selva indicate that trees have a rapid effect on nitrogen mineralization and phosporous balances (Montagnini 1988). Future monitoring of soil changes will occur in Phase II. A third year sampling will look at soil changes around the root zones of the seedlings. During the fifth year the plantation will be resampled when crown closure in the plots is expected to be completed. Other scientists are also encouraged to use the plantation for related studies in nutrient cycling, mycorrizal formation and eco-physiological research.

CONCLUSION

Successful forestry projects depend, in part, on the selection of species appropriate for the particular sites of the area and objectives of the end users. Native species are often overlooked as candidate trees as many foresters depend on research and techniques already developed in other parts of the tropics. Exotic species are used without any local comparative testing of native trees which may have high potential to grow well under plantation conditions, serve the wood needs of the local population and be benefical to indigenous wildlife.

Species screening trials using single tree plots can be a highly effective way to quickly gather comparative data on a wide range of species, both native and exotic. Furthermore, the information generated on native species: seed collection and germination, growth under different light and soil conditions, and tree/site interactions; lays the foundation for appropriate species selection for a wide range of forestry related work including reforestation, land restoration, agro-forestry, and wildlife programs.

The location of the project at a biological research station facilitates the use of the experimental plantations and research nursery by other interested scientists. Proposals have been written to conduct herbivory studies, eco-physiology and nutrient cycling research, photoinhibition studies, and socio-economic surveys of the local farmers. Scientists interested in conducting related research are encouraged to contact the author.

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LA SILVICULTURA DE ESPECIES LEÑOSAS MULTIUSOS: ALTERNATIVA DE DESARROLLO FORESTAL PARA EL TROPICO AMERICANO

Gonzalo De las Salas

Director Corporación Nacional de Investigación y Fomento Forestal (CONIF) BOGOTA, COLOMBIA

FDC: 26: 232.1: (213)

SUMMARY

The silviculture of multipurpose woody trees (MPWT) is emphasized as an alternative of forestry development for the american tropics. To support this statement the following considerations are briefly drawn: The deforestation of more than three million hectars/year of natural forest; The dependence of more than 1.500 million of persons from developing countries of firewood; the need of giving the rural poor the option to meet his basic needs like energy, food and housing.

The role of the MPWT in rural development aspects such as energy needs, food, environment, income and employment is pointed out. Themes of priority research on MPWT are discussed notably tree breeding, establishment, management and harvesting of forest plantations.

Some relevant experiences of projects dealing with the silviculture of more tham 30 forest species for firewood are commented. For the high Andes of South America the research has been concentrated on the following genus: Pinus, Eucalyptus, Cupressus, Acacia, Juglans, Alnus and Quercus. For the lowlands following species deserve mention: Anacardium excelsum, Cariniana pyriformis, Cordia goeldiana, Tectona grandis, Swietenia macrophylla, P. caribaea, Eucalyptus grandis, Gliricidia sepium, Leucaena leucocephala.

Perspectives about the silviculture of MPWT are given focused on soil protection and selection of species and provenances.

Following aspects are pointed out in research programs on MPWT: the importance of tree breeding, the overestimation of trials duration, the development of site index and growth models, the utilization of appropriate experimental designs, the lack of scientists with long experience, the inexistence of "miracle" trees and the need of publication of results.

Keywords: tree breeding, rural development, soil protection, multipurpose trees, American tropics.

INTRODUCCION

En septiembre de 1981, el Banco Mundial y la FAO presentaron el documento "Forestry Research Needs in Developing Countries; Time for a reappraisal?" al 17mo Congreso de la IUFRO en Kyoto, Japón. En este documento se definían las prioridades de la investigación forestal en países en desarrollo. Estas prioridades estuvieron enmarcadas dentro de los aspectos siguientes:

a. Desarrollo rural: Investigación sociológica, sistemas de finca incluyendo árboles, manejo de cuencas hidrográficas, vida silvestre.

b. Producción y uso de energía: Silvicultura de especies para leña, tecnología rural, derivados de la madera.

c. Manejo y conservación de recursos: Inventario, conservación, sistemas silviculturales.

d. Silvicultura industrial: Silvicultura y manejo, propiedades de las maderas.

Esta propuesta advertía que la silvicultura "clásica" practicada en los trópicos como herencia de los ingleses y franceses no era capaz por sí sola de resolver los problemas de la población rural que depende del bosque para satisfacer sus necesidades de madera, cobijo, energía y alimentación. Ejemplos cercanos en América Tropical se tienen en la Isla de Trinidad y en Surinam.

La silvicultura se encuentra hoy en los países en desarrollo en un estado crítico. En un futuro cercano, el reto más importante para América Latina será la plantación de árboles de uso múltiple, un mejor manejo de las plantaciones existentes y el aprovechamiento del bosque secundario. Esto, debido al hecho de que en las áreas cubiertas de monte productivo, éste se ha cortado pero no se ha replantado, mientras se registra un considerable avance de la erosión y desertización en varias regiones críticas. Asistimos -aparentemente impotentes- a la deforestación de más de tres millones de hectáreas/año de bosques naturales latifoliados del trópico húmedo americano. Frente a esta alarmante cifra, la proporción entre el área plantada y el área deforestada es de 1:10. Por otra parte, no podemos desconocer que sólo de la leña como alternativa energética en los países en desarrollo, dependen más de 1.500 millones de personas - (Palmberg 1981).

El análisis anterior nos obliga a poner la "ciencia de la silvicultura" al servicio de la sociedad.

ESPECIES LEÑOSAS DE USO MULTIPLE, (ELUM): SU PAPEL EN EL DESARROLLO RURAL DEL TROPICO HUMEDO AMERICANO 1/

1/Para los efectos del presente documento una especie leñosa de uso múltiple (ELUM) se define como un árbol o arbusto cultivado y manejado para más de un uso intencionalpara obtener productos y-/ o. servicios.

El papel de las ELUM en el desarrollo rural del trópico húmedo americano está asociado con los sistemas socioeconómicos, políticos y con los factores externos de cada región o país. La importancia atribuída a las ELUMS y los bienes y servicios derivados de éstas para las poblaciones rurales se puede sintetizar en los siguientes aspectos principales: Necesidades energéticas y de vivienda, alimentos y estabilidad ambiental e ingresos y empleo.

Necesidad energética y de vivienda

Cerca de mil millones de habitantes del tercer mundo depende de la madera como fuente de energía para la cocción de alimentos, la calefacción, la construcción rural y otros usos menores. Más de cien millones de campesinos del Tercer Mundo sufren actualmente de escasez aguda de leña que les impide satisfacer necesidades básicas para sobrevivencia.

En 1984 el consumo de madera como fuente de energía en los países en desarrollo superó los 1.100 millones de metros cúbicos anuales, con un contenido energético equivalente a 1.800 millones de barriles de petróleo (el consumo de petróleo de toda América Latina en el mismo año fue de aproximadamente 1.700 millones de barriles). Sin embargo, sólo un 20% del contenido energético de la madera es aprovechado por los métodos tradicionales de combustión directa. En términos promedio, la proporción del consumo total de energía atribuible a leña es de 20% en América Latina, 60% en Africa y 30% en Asia (Centeno, J.C. 1988).

La importancia del consumo de leña y carbón vegetal en América Latina es generalmente subestimada. La alarmante deforestación de las regiones secas y semisecas tiene su causa principal en el consumo de leña.

Alimentación y medio ambiente

El uso de la tierra más extendido en los trópicos húmedos es el de "roza, tumba y quema". Actualmente existen más de 200 millones de seres en esta área geográfica que practican este sistema en poco más de 300 millones de hectáreas de terrenos forestales para derivar su subsistencia. El aumento de la presión demográfica sobre las áreas de bosque húmedo ha forzado el acortamiento progresivo del barbecho a tal punto, que no es suficiente ni para restaurar la fertilidad del suelo ni para producir una biomasa forestal utilizable. El futuro de tales áreas, en las cuales es imposible mantener la productividad agrícola indefinidamente, hace imperante la necesidad de establecer sistemas de uso del suelo que contemplen la inclusión de especies leñosas de rápido crecimiento de uso múltiple, siendo uno de los más importantes el mejoramiento del suelo a través del aumento de la materia orgánica y el nitrógeno.

El mejoramiento del medio ambiente y por consiguiente, de la calidad de vida del habitante rural debe lograrse con métodos de producción estables, uno de los cuales es el de la ocupación del suelo con especies leñosas de uso múltiple.

Ingresos y Empleo

Los productos derivados de la cosecha de las ELUM, son una fuente de ingresos adicionales y de ahorro para el productor rural. En el trópico bajo, en donde la actividad ganadera está muy extendida, la madera utilizada para cercos, corrales, establos, portones, casas, horcones, jaulas y otras construcciones, constituye un elemento esencial para el funcionamiento de la finca. Por otra parte, muchos ganaderos están conscientes de la importancia de mantener bosquetes de protección de aguas, con lo cual contribuyen al mantenimiento del germoplasma y, parcialmente, de la fauna silvestre.

Otros productos como miel, frutas, forraje y leña entre los principales, contribuyen en gran medida a la economía familiar del pequeño productor rural. Un ejemplo interesante de citar es el del Nance (Byrsonima crassifolia) en Panamá; el fruto de esta leñosa se utiliza para hacer jugo ("chicha" en Panamá), el cual es muy apetecido en todos los restaurantes. Su demanda ha dado como resultado la creación de una agroindustria muy próspera.

La madera para construcción proporciona empleo para operarios locales y artesanos, así como suministro de materia prima para pequeños aserraderos. Se estima que un proyecto de plantación de ELUM puede generar empleo permanente durante la fase de vivero y los dos primeros años de plantación.

TEMAS DE INVESTIGACION PRIORITARIOS PARA LAS ELUM ACTUALMENTE UTILIZADAS

Propagación y mejoramiento de especies

Las ELUM, además de su reproducción por semillas, poseen la ventaja, casi todas, de propagarse vegetativamente. Esta es una circunstancia afortunada ya que en las zonas rurales se hace necesaria una forma fácil y barata de propagar los árboles y arbustos que han probado tener más de un uso o por lo menos un uso muy generalizado que amerite una investigación a largo plazo.

En la investigación de especies forestales es necesario tener un criterio claro sobre el uso más eficiente de la especie en cuestión y sobre las posibilidades de éxito del programa de investigación. La figura Nº 1 agrupa los elementos indispensables que deben tenerse en cuenta en la investigación de especies leñosas.

La propagación de las ELUM, como parte de la figura Nº 1, debe cumplir los objetivos siguientes:

a. Estudio de los problemas biológicos generales y fisiológicos en particular tales como diferenciación de tejidos, interacciones con factores climáticos y edáficos, influencia de las fitohormonas en el enraizamiento, comportamiento fenológico, entre los principales;

b. Establecimiento de huertos semilleros para el suministro de semillas

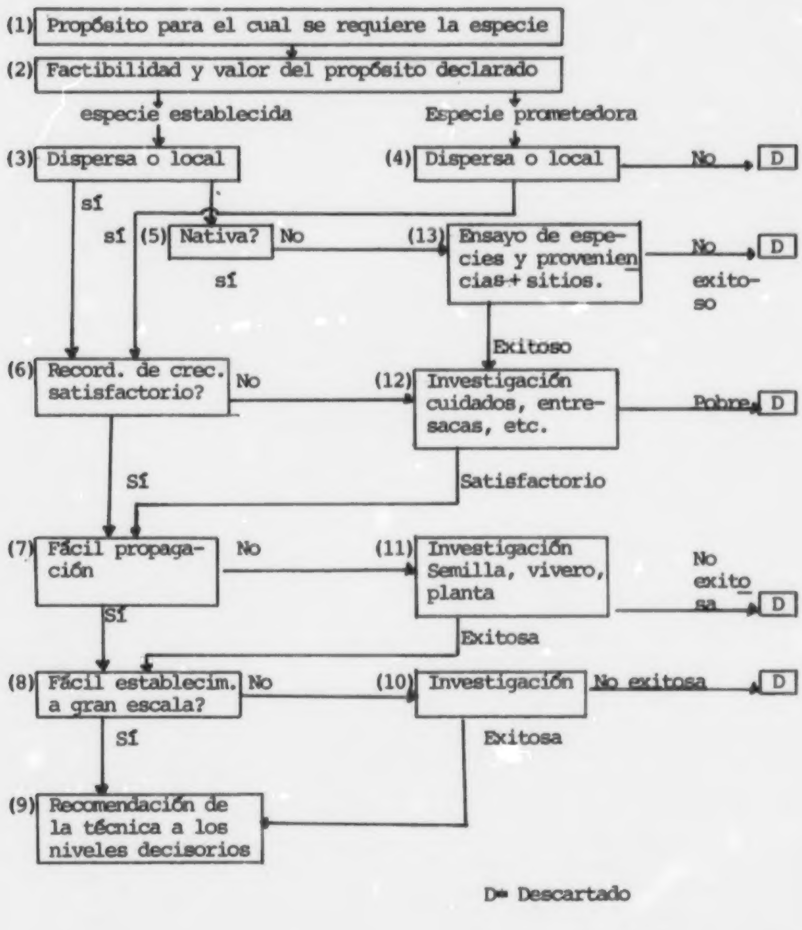

Figura Nº 1 Elementos a considerar en investigación de especies leñosas (según H.C. Dawkins, 1966)

genéticamente mejoradas;

c. Formación de colecciones de clones con el objeto de lograr la conservación de germoplasma de la o las especies que se deseen propagar;

d. Producción de material vegetativo en cantidades comerciales para la reforestación de sitios marginales en plazos cortos y con plantas genéticamente mejoradas.

La propagación vegetativa por medio de estacas es en la práctica, el método más utilizado en el trópico húmedo. Esta circunstancia debería aprovecharse para resolver de inmediato los problemas siguientes:

Especies que enraizan fácilmente; prendimientos de estacas de diferente tamaño; diferencias de enraizamiento entre estacas provenientes de diferentes posiciones en la copa de un árbol; estímulo de las fitohormonas al enraizamiento; optimización de la preparación y la producción de estacas; condiciones ambientales óptimas para propagación; adiestramiento de personal para las labores de propagación; evaluación del potencial de la manipulación genética (hibridación, cultivo de tejidos, polinización controlada).

E s t a b l e c i m i e n t o, m a n e j o y a p r o v e c h a m i e n t o d e p l a n t a c i o n e s.

La selección de los métodos silviculturales apropiados para el manejo del bosque natural es complejo, por una serie de razones que no cabe analizar aquí. La inconsistencia de su aplicabilidad se debe a una regeneración natural impredecible, su composición florística no siempre deseable, su largo plazo de producción, cosecha y regeneración, el aumento de la presión de la población y la inseguridad de predecir niveles de producción de especies valiosas y madera comercializable.

Frente a este hecho, el establecimiento y manejo de plantaciones leñosas de múltiple propósito, surge como una alternativa deseable y necesaria para la satisfacción de las necesidades de leña, cobijo, calidad ambiental y bienestar del habitante rural.

Las acciones, a nivel experimental, en el trópico húmedo americano se han concentrado en: Manejo de rebrotes; manejo de podas; manejo de la sombra (esta práctica es tradicional en el sistema de café con sombra de _Erythrina poeppigiana_ en Costa Rica); manejo del espaciamiento.

El caso del manejo de plantaciones de _Eucalyptus cloeziana_, _E. grandis_, _E. tereticornis_ y otras especies con turnos de corta de 6 años en el Brasil, se sale del contexto de una silvicultura social por tratarse de grandes extensiones.

El principal objetivo de la investigación sobre manejo de ELUM es evaluar la producción de biomasa, frutos, forraje, miel, etc. en función de la densidad y la edad del rodal.

Experiencias en Investigagación

Uno de los proyectos más grandes en América Tropical comenzó en Centroamérica en 1981 (su primera fase abarcó 5 años) siendo su objetivo central estudiar el comportamiento de especies forestales aptas para la producción de leña. Las especies seleccionadas en seis países centroamericanos fueron los siguientes (CATIE 1986):

Acacia mangium, Alnus acuminata, Azadirachta indica, Caesalpinia velutina Calliandra calothyrsus, Cassia siamea, Casuarina cunninghamiana, Casuarina equisetifolia, Eucalyptus camaldulensis, Eucalyptus citriodora, Eucalyptus deglupta, Eucalyptus globulus, Eucalyptus grandis, Eucalyptus saligna, Eucalyptus tereticornis, Gliricidia sepium, Gmelina arborea, Grevillea robusta, Guazuma ulmifolia, Leucaena diversifolia, Leucaena leucocephala, Melia azedarach, Mimosa scabrella, Tectona grandis.

La información analizada abarcó los aspectos siguientes: taxonomía, distribución natural, morfología, usos principales de la madera, requerimientos ambientales, regeneración natural e inducida, producción en vivero, prácticas de plantación, crecimiento y manejo, producción de biomasa y manejo de rebrotes.

Ocho de estas especies fueron escogidas para programas de investigación en zonas secas de México y El Caribe (Martínez y Hughes 1987).

En la zona Altoandina de América del Sur se ha conducido una serie relativamente grande de ensayos (Bauer, J. y Jan Llap, R 1987, CONIF 1989) con los géneros Pinus, Eucalyptus, Cupressus, Acacia, Juglans, Alnus y Quercus. Los resultados son preliminares y algunos de ellos controvertidos. La investigación silvicultural en Colombia con especies de zonas altas (2.700-3.400 m.) de diferentes procedencias, ha tenido un record de cinco años (CONIF 1989). Las siguientes especies se están ensayando en plantaciones piloto dado su buen crecimiento en altura y alta sobrevivencia: P. radiata (Chile), P. patula (Zimbabwe, Malawi, Suráfrica, Colombia), A. mearnsii (Colombia), Alnus jorullensis (Colombia), E. viminalis (Australia) E. nitens (Australia). Mención especial merece el programa clonal de mejoramiento de árboles de E. grandis de la Empresa Cartón de Colombia S.A. para elevaciones menores (2.000 m). El objetivo de este programa es aumentar la producción de esta especie de 25 m^3/ha/año a 40 m^3/ha/año con una generación (4.5 años) de selección de árboles plus, ensayos clonales y plantaciones monoclonales comerciales (Lambeth, C. y López. J. 1988). En la zona baja húmeda del trópico americano, se han ensayado con éxito en programas de fomento Anarcadium excelsum, Cariniana pyriformis, Cordia gerascanthus, Cordia goeldiana, Tabebuia rosea, Schizolobium parahyba, Tectona grandis, Terminalia ivorensis, Swietenia macrophylla, Carapa guianensis, Didimopanax morototoni, P. caribaea, E. grandis, Gliricidia sepium, y Grevillea robusta entre las principales.

PERSPECTIVAS

Protección del suelo bajo árboles de uso múltiple.

La reforestación es un método normalmente aceptable para reducir la erosión y regular las inundaciones al mismo tiempo que para proveer madera, leña, frutos, forraje, cercos vivos y otros productos. La función más importante de los árboles en la conservación del suelo es protegerlo contra la erosión laminar causada por el impacto directo de la lluvia.

La siguiente es una lista de características deseables de especies leñosas de uso múltiple para programas de conservación de suelos (De las Salas 1989, Young 1989): 1. buena sobrevivencia y crecimiento rápido en sitios pobres; 2. habilidad para producir gran cantidad de hojarasca; 3. fuerte y expandido sístema radical; 4. fácil establecimiento y necesidad de poco mantenimiento; 5. propiedad de reproducción vegetativa; 6. capacidad para formar una copa densa y mantener follaje durante gran parte del año; 7. resistencia a insectos, enfermedades y al ramoneo; 8. habilidad para mejorar el suelo (nitrificación por leguminosas); 9. provisión de retorno económico a corto plazo.

Selección de especies y procedencias

La selección de árboles para mejorar la productividad del suelo y prevenir la erosión, requiere una cuidadosa consideración. Plantar especies inapropiadas puede significar pérdida de esfuerzos, tiempo y dinero.

El ritmo de deforestación del bosque húmedo tropical y su escaso rendimiento indican que existe un incentivo evidente para el establecimiento de especies leñosas de uso múltiple mejoradas de diferentes procedencias en zonas de agricultura migratoria y en suelos empobrecidos.

Antes de embarcarse en proyectos de plantación de cierta escala, es conveniente llevar a cabo ensayos con las especies reportadas en la literatura como más promisorias para una región o localidad dada.

El número y tipo de ensayos difiere según las necesidades de los distintos países, pero es altamente deseable su cooperación mutua con el consiguiente beneficio para todos. Una ventaja adicional se conseguiría si los procedimientos detallados de los proyectos se unificaran en formularios o guías normalizadas con fines de comparación y evaluación posterior.

Burley y Wood (1979) sugieren que las actividades principales de investigación de especies y procedencias, a partir de las cuales se podrían formular programas, sean las siguientes:-

a. Revisión de literatura, correspondencia y conocimientos personales de distribución y variación de especies susceptibles de ser estudiadas.-

Discusiones con organizaciones internacionales y regionales que tratan con estas especies.

b. Elección de especies y de procedencias por ensayar.

(i) Selección de rodales parentales en el monte natural en cuanto sea posible, basada principalmente en su producción de semilla y calidad genética; (ii) Selección y ordenación de rodales semilleros en plantaciones, cuando sea posible; (iii) Obtención, tratamiento y almacenamiento de la semilla.

c. Diseño, trazado y análisis de experimentos de especies y procedencias.

(i) Evaluación y selección de estaciones; (ii) selección de sistemas silvícolas y ordenación; (iii) planificación y diseño de experimentos e interpretación; (iv) análisis e interpretación de datos experimentales; (v) informe y publicación de resultados.

d. Técnicas y evaluaciones en la etapa del vivero, incluídos métodos de comprobación en las etapas iniciales: (i) condiciones del vivero y tratamientos culturales; (ii) diseño y dirección de los experimentos en vivero; (iii) evaluaciones en vivero; (iv) métodos de comprobación de las primeras etapas, incluídos estudios bioquímicos y anatómicos, correlación juvenil-maduro.

e. Técnicas y evaluaciones en el bosque: (i) Definición de tipos de pruebas (plazo corto, mediano o largo) y sus objetivos; (ii) diseño y dirección de experimentos en el bosque; (iii) evaluaciones en el bosque, incluyendo: supervivencia, forma y rendimiento de árboles individuales y parcelas, calidad de la madera, los factores que influyen en ella, y sus implicaciones para la utilización.

Especies Promisorias

Se han identificado alrededor de 1.000 especies leñosas consideradas de uso múltiple en los trópicos americano, asiático y africano. El forestal tropical enfrenta el peligro de distraer esfuerzos de investigación en muchas especies que han fracasado o de las cuales se conoce muy poco. El cuadro Nº 1 muestra que el 85% de las plantaciones forestales en los trópicos está cubierta por tres géneros: pinus, eucalyptus y teca. Además de otros géneros como Swietenia, Cedrela, Cordia, Gliricidia, Gmelina y Leucaena en América Tropical, la silvicultura de los árboles multiusos es poco conocida.

Como una especie apropiada debe aportar los beneficios esperados, la matríz de opciones que debe investigarse (suelos, sitios, procedencia, usos etc.) limita el forestal (en tiempo y dinero) considerablemente en el alcance de esta meta. Datos comparativos de las mejores opciones para seleccionar la especie apropiada sobre todo en zonas socialmente marginadas, son sorprendentemente escasos.

Cuadro Nª 1. Especies utilizadas en plantaciones forestales tropicales* (Evans 1987).

Género/Grupo	(El orden indica la importancia relativa)	Porcentaje
Pinus	(patula, caribaea, elliotti, kesiya, merkussii, oocarpa, otros).	33.7
Otras coniferas	(Araucaria, cunninghamii, A. angustifolia, Cupressus, lusitanica, otros.	3.0
Eucalyptus	(grandis, camaldulensis, globulus* saligna, deglupta tereticornis, robusta, citriodora, urophylla, otros).	37.5
Teca	Tectona grandis	14.2
Otras especies	(Acacia, Gmelina, Meliacaea, Terminalia Albizzia, Triplochiton, otros).	11.6
		100.0

* No incluye datos del Sur de China, en donde las principales especies plantadas son Cunninghamia lanceolata, Pinus massoniana y P. yunnanensis.

**Solo exitosas en las zonas altas, principalmente en Colombia, Ecuador, Etiopia, India y Perú.

OBSERVACIONES FINALES

De la experiencia de varios proyectos de investigación sobre la Silvicultura de especies leñosas de uso múltiple en América Tropical, principalmente en Centroamérica, El Caribe, Colombia, Perú y Brasil, pueden resumirse algunos puntos relevantes.

a) No deben diseñarse programas demasiado rígidos: un experimento puede servir para varios objetivos;

b) La duración de los ensayos no debe sobrestimarse: muchos árboles multiusos alcanzan un crecimiento aceptable en dos o tres años y podrían utilizarse para programas de fomento;

c) La importancia del mejoramiento genético no debe desestimarse: la mayoría de las especies leñosas multipropósito se seleccionan de fuentes muy reducidas de germoplasma y el rendimiento no es un criterio de selección;

d) El desarrollo de modelos de índice de sitio tanto para rodales como para individuos no ha sido una meta en las investigaciones sobre ELUM. El índice de sitio sigue jugando un papel central en la predicción del crecimiento. Las funciones matemáticas utilizadas, los desarrollos recientes de modelos de crecimiento y la nueva tecnología computarizada, hacen posible el diseño de sistemas eficientes de muestreo (Grey D.C. 1989);

e) Los científicos de larga trayectoría con apoyo de largo plazo, son escasos; esa es una razón por la cual los programas de investigación de ELUM a largo plazo son casi desconocidos.

f) La investigación silvicultural sobre ELUM no debe catalogarse únicamente como "un problema para resolver". Es necesaria la investigación básica, por ejemplo: taxonomía, diversidad ecológica y fisiológica de las ELUM más utilizadas, influencias microclimáticas y edáficas, actividad fotosintética, dinámica de nutrientes, nodulación y fotoperíodos

g) La utilización de diseños experimentales simples y apropiados con objetivos claros no se ha destacado en varios programas de investigación sobre ELUM en el trópico americano. Es frecuente observar a investigadores jóvenes buscando al experto en estadística para que les interprete confusos resultados y logre evaluar el experimento como "significativo" con cualquier nivel de confidencia. Huxley (1989) comenta que en términos prácticos y dependiendo de los objetivos de una investigación en particular, los siguientes aspectos influyen sobre el diseño experimental a utilizarse: a) la escogencia y número de unidades experimentales; b) la identificación de cómo se combinan mejor estas - nidades. Indudablemente la investigación de campo requiere considerable habilidad para resolver situaciones conflictivas;

h) Los árboles "milagrosos" no son aceptados facilmente por el campesino.

El interrogante básico en el manejo de especies y sitios es si los productos obtenidos cumplen los beneficios buscados encaminados a llenar el requisito de la silvicultura social: " El bosque es para la gente".

i) Los resultados de la investigación silvicultural han sido tímidamente divulgados y ésto dentro de un limitado número de investigadores y usuarios.

j) La pobreza ha sido la causa principal de la deforestación en los trópicos. En las zonas tropicales viven aproximadamente 2000 millones de personas en un incremento anual de un 2.6 por ciento que descuajan extensas superficies de bosque. La plantación de especies forestales multiusos se vislumbra como una alternativa para disminuir la tasa de deforestación y brindar al habitante rural la opción de estabilizarse y cubrir sus necesidades básicas de techo, energía y alimento.

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MICROPROPAGATION OF TWO TROPICAL PINES: *PINUS CARIBAEA* AND *PINUS KESIYA*

Saturnina C. Halos and Nancy E. Go

Researcher IV and Research Assistant
Natural Sciences Research Institute

University of the Philippines
Diliman, Quezon City

FDC: 165.442: 174.7 *Pinus caribaea* Morelet.: 174.7 *Pinus kesiya*

SUMMARY

Adventitious shoot formation was induced in excised embryos of *Pinus caribaea* and *Pinus kesiya* in a BAP-supplemented modified Murashige and Skoog medium (MSM). Highest frequency of bud production was obseved when embryos were exposed to BAP for one week at 2 mg/l BAP for *P. caribaea* and 10 mg/l BAP for *P. kesiya*. Dilution of the MSM basal medium to 1/4x decreased shoot formation in *P. caribaea* but favored that of *P. kesiya*. The concentration of sucrose and vitamins did affect bud formation while increased ammonium nitrate caused browning of explants. Rooting for both species was optimum in medium supplemented with 1uM NAA and 1.5% sucrose

INTRODUCTION

Our interest in the tropical pines *Pinus caribaea* and *Pinus kesiya* stems from the fact that these two species are fast-growing with growth rates as high as 35 cu m per ha per year reported for 15 year old stands. Their survival rates in poor, depleted, acidic soils is high at 65-98% depending upon the maintenance regime. Further, these two species are deemed commercially feasible for pulp-wood production. In addition, *P. kesiya* timber is used for mine props and for furniture manufacture. It also yields oleoresin from which turpentine, essential oils and resin are extracted for the manufacture of paints, varnishes, air freshners and glues. Communities living within or near the natural pine forests not only gather oleoresin for livelihood but also mature pine cones for handicraft items.

Unfortunately, pine plantations and natural stands in the Philippines are being destroyed by insects, notably shoot moths (*Dioryctria rubella* and *Petrova cristata*) and a bark beetle

(*Ips* sp.) and by a major disease, pine needle blight. The shoot moth infestations in newly established plantations have reached epiphytotic proportions that further plantings have been stopped. On the other hand, the natural pine forests are reduced in area due to *Ips* infestation. In view of these problems, there is an urgent need to establish breeding programs that would yield trees that are not only resistant to these pests and diseases but are also of rapid growing rates and improved quality.

Considering the long life cycles of these two pine species, developing tissue culture techniques would be most useful to such breeding programs. If properly developed, tissue culture can be used to rapidly propagate selected trees for well-designed field trials and/or plantation establishment. Selections can be made in the laboratory at the cellular, tissue and plantlet level, thereby reducing the time and expense of establishing and maintaining large breeding populations.

Successful micropropagation techniques have been reported for several conifer species. most of which using embryonic explants. Adventitious buds have been produced using explants such as mature embryo (Sommer and Bermudez 1987, Zel et al 1988, Reilly and Washer 1977, Cheng 1975, Horgan and Aitken 1981, von Arnold and Eriksson 1980, von Arnold 1982, Patel and Thorpe 1984, Webb and Santiago 1983), cotyledon (Mott and Amerson 1981, Aitken et al 1981, David et al 1982, Bornman 1981, Franco and Schwarz 1985), hypocotyl (Franco and Schwarz 1985), epicotyl (Rumary and Thorpe 1984) and shoot tip (Horgan and Aitken 1981, Skidmore et al 1988). Explants from mature trees have also been used such as shoots and elongating needles (David et al 1982, Jansson and Bornmann 1980, 1983, von Arnold and Eriksson 1979, von Arnold and Tillberg 1987) but yields were generally smaller. So far, no report has been made on the successful plantlet regeneration of *P. caribaea* and *P. kesiya*.

This paper describes a method for successful plantlet regeneration in *Pinus caribaea* and *Pinus kesiya* using mature embryos as explant. Factors affecting efficiency of shoot and root formation have been investigated.

MATERIALS AND METHOD

Seed Source

Seeds of *Pinus caribaea* were obtained from the Danida Forest Seed Center. These seeds which were collected from Queensland has been a select provenance developed from Mt. Pine Ridge and has been the highest producer of all provenances tested (Gibson et al 1983). The seeds of *Pinus kesiya* were given by the Philippines' Forest Management Bureau which were collected from Bobok, Mt. Province, Philippines.

Seed Sterilization

Seeds were soaked in 10% Chlorox (5.25% NaOCl) v/v for 30 minutes, in 70% ethanol for 2 minutes and rinsed twice with sterile distilled water. The seeds were then soaked overnight in sterile distilled water.

Culture Conditions

All cultures were maintained under a 16-hr photoperiod at 25-27°C. Illumination was provided by fluorescent lamps (General Electric). All media were adjusted to pH 6.0 prior to autoclaving at 15 psi at 121°C for 15 minutes.

For P. caribaea excised embryos were cultured on a basal medium consisting of a modified Murashige and Skoog Medium (MSM)(Franco and Schwarz 1985) supplemented with 3% sucrose, 0.5% Phytagar and different concentrations of 6-Benzyladenine (BAP) at 2, 5, 10, 15 mg/l. Exposure times were 1, 2 and 3 weeks afterwhich the embryos were transferred to either 1x or 1/2x MSM supplemented with 2% sucrose. In subsequent experiments looking for the effects of varying levels of sucrose, salts, vitamins and NH_4NO_3, embryos were cultured in MSM supplemented with 3% sucrose and 2mg/l BAP for one week prior to transfer to the basal medium to be tested.

The same procedure was adapted for P. kesiya. However, in subsequent experiments only the effect of varying basal medium concentrations was tested.

Elongated shoots produced from the various bud induction media were collected and were used randomly in the rooting experiments. Roots were induced in 1/2x Cuppressus Basal Medium (Franco and Schwarz 1985) supplemented with 1% sucrose, 0.35% Phytagar and various concentrations and combinations of auxins (NAA, IBA, IAA) at different exposure times. After the root induction period the shoots were transferred to 1/2X of a modified Gresshoff and Doy Medium (Franco and Schwarz 1985) with 1% sucrose for root elongation. Using 1uM NAA, the effect of different levels of sucrose was also investigated.

Statistical Analysis

When applicable, data were subjected to ANOVA and T-test at 0.05 level of significance.

RESULTS AND DISCUSSION

A d v e n t i t i o u s S h o o t F o r m a t i o n

Adventitious shoot formation was induced on cultured embryos upon exogenous application of 6-benzyladenine (BAP). Intact white embryos swelled and became green within 3-6 days in culture and root formation was inhibited. In contrast, explants grown on BAP-free medium developed into normal seedlings.

The morphological changes that accompanied shoot formation started with the appearance of granular structures on the surface of the explant, most of which were concentrated on the cotyledons (Figure 1a). These structure were similar to the developing shoot primordia described by Yeung et al (1981). These continued to develop into a mixture adventitious buds and needle rosettes (Figure 1b). The final stage of development involved shoot elongation (Figure 1c).

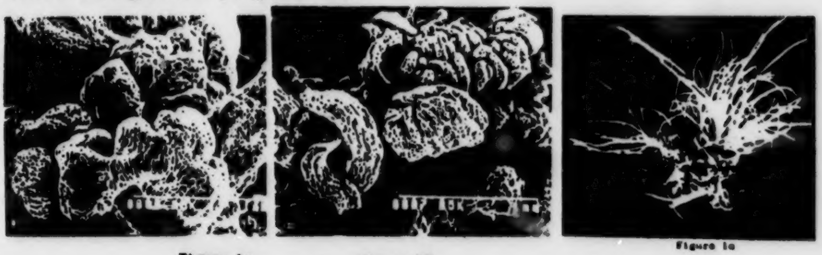

Figure 1a Figure 1B Figure 1c

Figure 1. Scanning electron micrographs of (a) granulated surface of embryos showing developing bud primordia and (b) mixture of adventitious buds and needle rosette. The stage where shoots were elongating (c).

Pinus caribaea

Factors that influenced the bud-forming capacity of embryos of *P. caribaea* were investigated. At high concentrations of BAP the frequency of explants forming buds decreased although the mean number of shoots remained the same. Table 1 shows that significantly higher number of embryos produced adventitious buds at BAP concentrations of 2 and 5 mgl/ compared with those treated with 10 and 15 mg/l BAP. Those that did not form buds eventually turned brown and died. Shoot elongation was also observed to be relatively slow at these these higher concentrations as compared to 2 and 5 mg/l (Figure 3). This response was also noted in *Pinus sylvestris* (Zel et al 1988), *Pinus contorta* (Patel and Thorpe 1984) and *Pinus elliottii* (Sommer and Bermudez 1987). Higher dosages of BAP appear to be deleterious as high percentage of

browning was observed in explants cultured in high concentrations and longer exposures to the hormone.

Table 1. Adventitious bud production in P. caribaea embryos as affected by hormone concentration*

Conc. of BAP (mg/l)	Proportion of embryos forming buds (%)	Range in the number of buds/embryo	Mean number of shoots/embryo
2	24/25 (96)	1-30	9[a]
5	19/24 (79)	4-41	9[a]
10	9/23 (39)	1-22	9[a]
15	8/21 (38)	6-21	10[a]

*Values with the same superscript are not siginificantly different

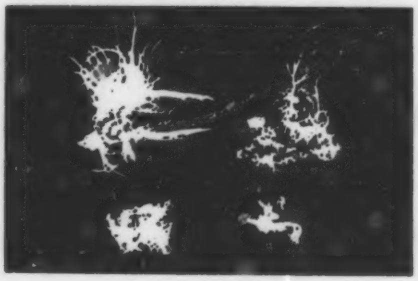

Figure 2. Extent of shoot elongation as affected by one week exposure to different concentrations of BAP, after 10 weeks in culture; (a) 2 mg/l, (b) 5 mg/l, (c) 10 mg/l and (d) 15 mg/l

The length of exposure to BAP also showed a significant effect in the frequency of bud formation (Figure 3). For all BAP concentrations tested, the most number of multiple bud-forming embryos were observed among those exposed to BAP for shorter periods of time. One week incubation in the hormone was found to be optimum.

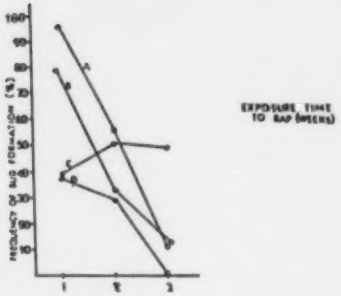

Figure 3. Frequency of bud formation as affected by length of exposure to BAP, (a) 2mg/l, (b) 5 mg/l, (c) 10 mg/l and (d) 15 mg/l.

Table 2 shows the effect of decreasing the concentration of the basal medium. The mean number of buds produced per explant significantly decreased at 1/4x and 1/8x of the basal medium (salts and vitamins) but no difference was observed between 1x and 1/2x. The concentration of NH_4NO_3 was also very critical in the survival of the explant. Doubling the amount of this salt resulted in the browning of all explant within a month of culture. Similar responses to increased NH_4NO_3 were recorded for Pinus elliottii (Bermudez and Sommer 1987).

Table 2. Adventitious bud production as affected by concentration of basal medium*

Conc. of basal medium	Proportion of embryos forming buds (%)	Range in the number of buds/embryo	Mean number of shoots/embryo
1X	24/25 (96)	1-30	9^a
1/2X	31/35 (89)	1-19	6^a
1/4X	16/25 (64)	1-8	3^b
1/8X	21/25 (84)	1-6	3^b

*Values with the same superscript are not significantly different.

Increasing the sucrose level of the medium up to 4% did not significantly affect the bud-forming capacity of the explants (Table 3). However, it was noted that shoot elongation was relatively faster 3% and 4% sucrose as compared to 2%. Moreover, the shoots produced were greener and appeared healthier.

Table 3. Adventitious bud production as affected by sucrose concentration*

Conc. of sucrose	Proportion of embryos forming buds (%)	Range in the number of buds/embryo	Mean number of shoots/embryo
2%	24/25 (96)	1-30	9[a]
3%	23/33 (70)	1-26	7[a]
4%	16/25 (64)	2-15	6[a]

*Values with the same superscript are not significantly different.

Adventitious bud production was not also sigficantly affected when the concentration of the vitamins was decreased half-strength or increased by replacing MSM vitamins with that of Shenk and Hildebrandt's (Bornman 1981). Addition of pyridoxine and nicotinic acid, which were absent in MSM but present in SH, had likewise no effect.

Table 4. Adventitious bud production as affected by vitamin concentration*

Conc. of vitamins	Proportion of embryos forming buds (%)	Range in the number of buds/embryo	Mean number of shoots/embryo
1X	13/20 (70)	1-12	5[a]
1/2X	31/35 (89)	1-19	6[a]
SH**	22/25 (88)	1-9	4[a]

*Values with the same superscript are not significantly different.
** The vitamins of MSM were replaced by that of Shenk and Hildebrandt's (Bornman 1981).

Pinus kesiya

Full-strength concentration of the basal medium was found to cause widespread browning in P. kesiya embryos wherein survival was recorded at only 8% (Table 5). The frequency of bud formation significantly increased when the concentration was reduced to half-strength (Table 5). Studies are underway to determine to which nutrient group P. kesiya has been particularly sensitive.

Table 5. Adventitious bud production as affected by concentration of basal medium*

Conc. of basal medium	Proportion of embryos forming buds (%)	Range in the number of buds/embryo	Mean number of shoots/embryo
1X	2/24 (8)	2-4	3[a]
1/2X	8/12 (67)	4-11	5[a]
1/4X	8/18 (45)	4-6	5[a]

*Values with the same superscript are not significantly different.

Frequency of bud formation was also affected by the concentration and length of exposure to BAP. Bud production was highest at 10 mg/l of BAP but significantly decreased at 15 mg/l (Table 6). On the other hand, similar to P. caribaea, bud production in P. kesiya remained related to length of exposure (Figure 4). Apparently, P. kesiya could tolerate higher concentrations of BAP but lower concentration of the basal medium as compared to P. caribaea.

Table 6. Adventitious bud production in embryos as affected by hormone concentration*

Conc. of BAP (mg/l)	Proportion of embryos forming buds (%)	Range in the number of buds/embryo	Mean number of shoots/embryo
2	9/20 (45)	1-11	5[a]
5	7/14 (50)	5-17	9[a]
10	8/12 (67)	4-11	5[a]
15	2/13 (16)	2-4	3[a]

*Values with the same superscript are not significantly different

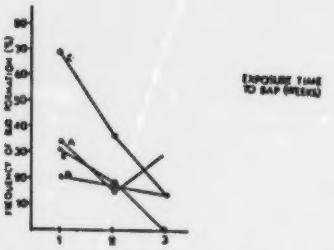

Figure 4. Frequency of bud formation as affected by length of exposure to BAP, (a) 2mg/l, (b) 5 mg/l, (c) 10 mg/l and (d) 15 mg/l.

Rooting of Adventitious Shoots

Rooting in conifers generally requires exogenous application of auxins (Mohammed and Vidaver 1988). In our study, elongated shoots of <u>P. caribaea</u> and <u>P. kesiya</u> were collected and randomly used in the rooting experiments. Though rooting occurred at 5-13% in media not supplemented with auxin highest root formation was observed with the application of 1uM NAA (Table 7). The number of roots formed in the different treatments vary from 1 to 5.

Table 7. Percentage of root production using different auxin treatments after 8 weeks in culture

Hormone treatment	Length of exposure (weeks)	Shoots forming roots (%)*	
		PC	PK
0.1 µM NAA	2	0	NT
1.0 µM NAA	1	11	33
	2	28	35
1.5 µM IBA	2	0	NT
10.0 µM IBA	1	5	11
	2	22	7
1 µM NAA + 10 µM IBA	2	10	20
100 µM IAA + 100 µM IBA	24 hrs	11	NT

*PC = <u>P. caribaea</u>, PK = <u>P. kesiya</u>, NT = not tested

The influence of sucrose concentration on root formation is shown on Table 8. Removal of sucrose in the medium resulted to low frequency (4-9%) and delayed (12-26 weeks) root formation. Optimum rooting was observed at 1.5% sucrose.

Table 8. Root formation as affected by sugar concentration

Sugar Concentration (%)	Shoots forming roots (%)*	
	PC	PK
0.5	0	24
1.0	15	30
1.5	35	44
2.0	27	30

*PC = P. caribaea, PK = P. kesiya

The frequency of rooting among excised shoots in P. caribaea and P. kesiya is still low, the highest being 35% and 44% respectively for each species. Franco and Schwarz (1985) had observed the same low frequency of rooting in Pinus oocarpa. Eriksson (1989, personal communication) attributes this low rooting frequency to the preventive effect of BAP and has suggested the use of substitutes for BAP in bud induction.

CONCLUSION

The procedures for plantlet regeneration from mature embryos decribed above for P. caribaea and P. kesiya are essentially similar to those described for other pine species. The procedure involves various treatments for induction and proliferation, shoot elongation and root induction. These two species differ from other species as well from each other on their reaction to varying concentrations of the growth hormones and basal media used.

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Experience in MPTS Network Research in Asia [1]

Kenneth G. MacDicken [2]
E. Lee Medema [2]
Kamis Awang [3]
Suree Bhumibhamon [4]

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Abstract

Networking has been recognized as a useful, cost-effective means of enhancing research on multipurpose tree species. In 1986, the Multipurpose Tree Species Research Network was formed with support from the Forestry/Fuelwood Research and Development Project, funded by the U.S. Agency for International Development. Now active in over 20 institutions in Asia, the F/FRED Project and the MPTS Research Network have been successful in conducting a wide range of research and training activities. Successful network activities described in this paper include establishment of a functioning committee structure, cooperative network experiments, leucaena psyllid research, tree improvement research and a regional study on farm and village forest use practices.

BACKGROUND

The Seventh World Forestry Congress in Jakarta in 1978 recognized that forests should serve the people. At this meeting the need to manage natural forests and build up forest resources by planting fast-growing multipurpose trees to provide sustainable supplies of tree products for household use and/or as a profitable source of income for rural populations was repeatedly stressed. It was also recommended that the new strategy be based on the active and voluntary participation of rural people in growing trees.

Following the 1978 Congress and an FAO paper on Forestry Research needs in developing countries (FAO, 1980), a reappraisal was presented at the 1981 International Union of Forestry Research Organizations (IUFRO) Congress in Japan. The adoption of a resolution on forestry research priorities in developing countries has stimulated further IUFRO activities to review and promote research in Asia. IUFRO organized a regional workshop on increasing productivity of multipurpose tree species in Kandy, Sri Lanka in 1984. This was the first time that forest scientists in the region discussed directly two issues concerning multipurpose tree species (MPTS)

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[1] **Paper presented at the XIX World Congress of the International Union of Forestry Research Organizations, Montreal, Canada, August 5-11, 1990.**

[2] **Winrock International, F/FRED Coordinating Unit, Faculty of Forestry, Kasetsart University, Bangkok, Thailand**

[3] **Faculty of Forestry, Universiti Pertanian Malaysia, Serdang, Malaysia**

[4] **Department of Silviculture, Faculty of Forestry, Kasetsart University, Bangkok, Thailand**

- increasing productivity and improved utilization of multipurpose tree species. Priority species were selected and priority research activities were identified. Lead institutions were identified to conduct and coordinate this research (Shea and Carlson, undated).

One follow on to this meeting is the Forestry/Fuelwood Research and Development (F/FRED) Project, funded by the United States Agency for International Development (USAID) and administered by Winrock International. This project has played a leading role in networking following the recommendations of the Kandy Meeting.

Networking

Burley (1987) defines agriculture and forestry research networks as "informal or formal arrangements of cooperation between institutions with similar conditions and problems but without the immediate resources for finding solutions to these problems individually." Considering this general definition, it is obvious that the concept of networks is not new but dates from the beginnings of institutionalized science. Communication between researchers, the sharing of hypothesis, research methods, genetic materials, professional society meetings and cooperative research projects are common elements of "networking" which have existed in some form for centuries.

The concepts of research networking is also not unique to the F/FRED Project. Consider the following types of existing networks (MacDicken, 1989). First, some networks are loosely grouped associations of researchers who divide research problems into work assignments, either formally or informally. An example of informal division of topics is the Northern Thailand Natural Resources Management Network (NORMNET). This is composed of an advisory group of agency officers and researchers, whose members jointly identify and help allocate funds for research projects of relevance to the participating development agencies. The formal division of topics is found in the approach adopted by the IUFRO Kandy meeting in 1984 which identified lead institutions to conduct and communicate research on specific topics.

Second, networks can be groups of participants who conduct a set of centrally coordinated experiments to solve specific research problems. This approach concentrates greater resources on a well-defined problem, and is often used by international agricultural research centers to test food crop varieties (Plucknett and Smith, 1984). Rice variety trials coordinated by the International Rice Research Institute (IRRI) and network experiments on multipurpose tree species supported by the F/FRED Project are examples of this type of network. This type of network is also typified by the International Research Development Centre (IDRC) - sponsored Bamboo and Rattan Research Network which conducts research projects with grants provided by the IDRC.

Other networks are primarily communications-oriented and are comprised of groups of people who communicate regularly in areas of common interest. Organizations which produce research publications and newsletters such as the Nitrogen Fixing Tree Association (NFTA) and the Asian Forestry Education Network exemplify this type of network.

Some networks provide a wide range of services and support among network participants. This type of "integrated network" combines aspects of all three of the above concepts. It facilitates the training and development of network participants and includes publications and research components. Examples of this type of network are the MPTS Research Network which is supported by the F/FRED Project and the International Board For Soil Research and Management Incorporated which supports research networks on soil and land management.

THE MPTS RESEARCH NETWORK AND THE F/FRED PROJECT

The F/FRED Project is a ten-year effort funded by USAID. It is designed to help scientists cooperatively address the needs of small-scale farmers for fuelwood and other tree products. The Project has helped to initiate and support the establishment of the MPTS Research Network which has over 20 participating institutions in 11 countries in South and Southeast Asia and the Pacific. Mechanisms for network development include scientific and organizational meetings, cooperative research projects, long and short-term training, travel grants, publications and small research grants. The F/FRED Project has worked in close collaboration with Kasetsart University and a number of donor organizations in supporting network activities.

The MPTS Research Network is built upon informal national-level networks which are being established and formalized through a series of National MPTS Research Meetings held annually in most of the participating countries. The primary objectives in supporting these meetings is to provide an integrated and open forum for discussion of MPTS research issues, provide national level links to the regional research network, monitor and evaluate on-going F/FRED-funded research projects, develop a prioritized list of MPTS-related research topics, and select representatives to serve on the MPTS Research Network Research Committee. In addition, a number of countries have initiated national level research programs on MPTS. Thailand, Malaysia, Papua New Guinea and Sri Lanka have established formal National MPTS Research Committees. Indonesia has established a National MPTS Research Secretariat to carry-on national level network development on MPTS.

The MPTS Research Network is guided by a Research Committee and a Steering Committee. The Research Committee consists of two representatives from each participating country (a social scientist and a biological scientist) who are selected in conjunction with the Project-supported National MPTS Research Meeting. The Research Committee recommends network research direction, priorities and policies. The Steering Committee gives the network general direction and guidance and reviews Research Committee recommendations. The Steering Committee is made up of four members selected by and from the Research Committee and three members defined by position. The positions include (1) the ranking Asian member of IUFRO, (2) the FAO Regional Forestry Officer for Asia and the Pacific, and (3) the Dean of the Faculty of Forestry at Kasetsart University, the institution that hosts the F/FRED Coordinating Unit.

The field operations of the F/FRED Project have been largely successful in establishing the MPTS Research Network (Butterfield *et al.*, 1988). During the first three years of network establishment most network activities have been managed by the F/FRED Coordinating Unit housed at the Faculty of Forestry, Kasetsart University in Bangkok, Thailand. However, several important sub-projects such as a national-level network of researchers working on *Azadirachta indica* and *Melia azedarach*, have been initiated by the Kasetsart University Faculty of Forestry. A regional research program on the leucaena psyllid has also been initiated, coordinated and managed by network participants.

The F/FRED Project has invested over US$8.9 million over a five year period in helping to establish the MPTS Research Network, support MPTS research and upgrade the training of MPTS researchers. USAID plans to provide additional funding for a second five year phase beginning in early 1990. While details of the second phase of the Project are not yet available, efforts to broaden financial support for the MPTS Research Network will certainly be a part of the long-term objective. Commitments from other donors to MPTS Research Network activities have exceeded US$500,000 in the first phase. Indeed, donor and national support for network programs has been excellent, although it has always been for specific activities on a case by case basis. Participating network institutions have contributed significantly to network programs through co-financing and provision of staff and facilities.

Examples of Cooperative Network Research

The major research efforts of the F/FRED Project include network trials, leucaena psyllid research, tree improvement and social science studies.

Network trials

At the 1986 Forestry Networks Workshop in Bangkok, there was a consensus to establish a standardized set of field trials in the humid and sub-humid zone of Asia. This was followed by a planning meeting in Kuala Lumpur, Malaysia in December 1986, where Asian scientists designed the first of five series of network experiments supported by F/FRED. The following features were incorporated in the planning:

- o common design and standardized methodology;
- o common minimum data set to be collected;
- o common germplasm;
- o the same experiment on multiple sites;
- o thoroughly described soils and climate at each site;
- o data exchange and professional interaction between participants; and
- o intersite combined analysis of data

In general, the field trials aimed to improve the productivity and utility of short-rotation trees in meeting fuelwood and other needs (e.g. fodder) of small-scale farmers in developing countries, and provide farmers with a number of options appropriate to their conditions. The network trials were established specifically to serve three purposes:

- o to enhance the knowledge of growth rates, site requirements, and management practices of several priority multipurpose tree species through the generalization of experimental results that multi-location testing allows;

- o to provide a focus for network development similar to that used by successful agricultural research networks; and

- o to help improve and standardize research methodologies used in forestry research.

Humid Zone Network Trials

The first series of network trials were established in the Humid and Sub-Humid Tropics in 1987. The experimental design selected was a randomized complete block with four replications comparing two provenances of three species, under three management practices. The three management practices were:

- o pollarding at 2 meters at the age of 24 months;
- o pruning up to 50% of the total stem height at the age of 18 months; and
- o no cutting at all.

As an example of the value of the network trials, one year data from eight sites are summarized here (Table 1). The eight sites are located in Baybay, Leyte, Philippines (PV01), Dramaga (IF01) and Cikampek, West Java, Indonesia, Serdang (MP01) in Malaysia, Lad Krating A(TK01), Uthai Thani (TK02) and Ratchaburi (TS01) in Thailand and in Henchu, Republic of China (Taiwan) (CF01). Four of the sites have udic moisture regimes, while the other four have ustic moisture regimes.

Analysis of height, diameter breast height and biomass indicated significant differences among sites and among species. The interactions between site and species as well as site and genotypes were also highly significant, demonstrating the variation in environmental requirements among the species and genotypes. Differences between the genotypes were very highly significant in terms of height growth but not in diameter growth.

Growth in terms of height, diameter and biomass production was generally the best on site TK02 and the poorest on site CF01. For the ustic sites (TK01, TK02, TS01 and CF01) the two leucaenas performed better than the acacias in terms of height growth. The acacia species performed better on the four udic sites (PV01, IF01, IF02 and MP01).

These preliminary data from the first series of multi-location trials of MPTS in Asia demonstrate the value of this approach. Future analysis of genotype x environment interactions and environmental modeling will provide significant new information on site requirements of the materials included in these experiments. Farmer-oriented management treatments should reveal a great deal about the trade-offs of multipurpose management of trees used by small farmers for fuelwood, fodder and other tree products.

Over 50 field experiments have been established to date through the MPTS Research Network with F/FRED support. This has included network experiments with tissue cultured plantlets, provenance trials and experiments in the arid and semi-arid zones. In addition to generating valuable research data one of the

Table 1 Height, diameter and total biomass at one year after transplanting

Genotype [1]	Experiment site name								
	PV01	IF1	IF02	MP01	TK01	TKO02	TS01	CF01	MEAN
				Height (m)					
Mang.-Qld	5.8ab [2]	5.8a	3.8ab	2.4c	4.3c	6.0bc	3.5ab	1.5d	4.1
Mang.-PNG	6.0a	6.2a	3.7b	3.1ab	4.2c	6.2b	3.3b	1.7cd	4.3
Auri.-Qld	5.4b	4.9b	4.2a	3.5a	4.6bc	5.8bc	3.6ab	2.[illegible]ab	4.3
Auri.-PNG	5.4b	4.5b	3.2	3.6a	4.2c	5.5c	3.1b	1.9bc	3.9
Dive.-156	5.6ab	3.3	2.1c	2.5bc	4.9ab	7.1a	4.8	2.1ab	4.1
Hybr.-KX3	4.3	2.2	2.4c	2.0c	5.2a	7.2a	4.0a	2.3a	3.7
			Diameter at breast ht (cm)						
Mang.-QLD	5.2a	4.6a	2.9a	2.2bc	3.5a	5.1a	3.4ab	1.2a	3.5
Mang.-PNG	5.4a	4.8a	2.9a	3.4a	3.5a	5.4a	3.5a	1.1a	3.8
Auri.-Qld	3.6b	3.1b	3.0a	3.0ab	3.1b	3.9c	7.5c	1.1a	2.9
Auri.-PNG	4.0b	3.1b	2.1	3.6a	2.9bc	3.8c	2.6c	1.1a	2.9
Dive.-156	2.9c	1.3c	1.2b	1.8c	2.8c	4.3b	3.7a	1.2a	2.4
Hybr.-KX3	2.4c	1.1c	1.5b	1.4c	3.2ab	4.4b	3.1bc	1.5a	2.3
			Total biomass (kg/tree)						
Mang.-Qld	5.1ab	2.5a	0.8a	0.6a	4.0a	5.9ab	2.1ab	0.5b	2.7
Mang.-PNG	6.5a	3.2a	0.7a	1.0a	4.4a	5.4bc	2.6ab	0.7ab	3.1
Auri.-Qld	2.8cd	2.1b	0.8a	1.2a	2.7ab	3.3c	2.4ab	0.9ab	2.0
Auri.-PNG	3.8bc	2.5b	0.8a	1.1a	4.0a	4.6bc	3.1a	1.0a	2.6
Dive.-156	1.5de	0.6c	0.2b	0.3b	2.2b	3.1c	3.2a	0.6ab	1.5
Hybr.-KX3	1.0a	0.1c	0.2b	0.4b	3.8a	8.0a	1.6b	0.7ab	2.0

[1] Mang-Qld: Acacia mangium, Queensland provenance
Mang-PNG: Acacia mangium, Papua New Guinea provenance
Auri-PNG: Acacia auriculiformis, Papua New Guinea provenance
Auri-Qld: Acacia auriculiformis, Queensland provenance
Dive-156: Leucaena diversifolia, K156
Hybr-KX3: Leucaena hybrid (L. diversifolia x L. leucocephala)

[2] Values within sites not followed by a common letter are significantly different at P-0.05 using Fisher's LSD test.

main purposes of the trials is to help promote networking among scientists. The trials help to meet such aims by encouraging peer review, and by focusing group effort on a single common activity. The cooperators in the network conducted a field tour in October, 1988 to review the progress and problems with the experiments in Thailand, Malaysia, Indonesia and Philippines. Experiments are all designed by participants in the trials, network coordinators and in some cases special resource persons.

Counterpart financial support to these trials has been critical to the long-term building of participating institutions and research programs. Participation in the network trials has in many cases also provided short-term training opportunities and limited equipment support. Yet, the indirect costs of land, professional staff salaries, equipment, administration, etc. have been borne by the institutions cooperating in the experiment. In this way, the provision of modest levels of F/FRED support for network trials requires a commitment to network research by cooperating institutions.

Leucaena psyllid research

The leucaena psyllid (*Heteropsylla cubana*) is a tiny homopterous insect which has infested *Leucaena leucocephala* in Asia and the Pacific, causing widespread economic damage. The impact of this pest on leucaena production and use has resulted in leucaena psyllid research programs in more than ten countries in the region. Common interest in finding solutions to the psyllid problem has led to cooperative planning of research, increased communication and coordination between researchers and additional funding by institutions such as the IDRC, USAID and national research programs. Research interest in the psyllid has also resulted in the production of a regional research plan and regular communications between national programs (Napompeth *et al.*, 1987).

The process of regional research cooperation on the leucaena psyllid has followed a step by step process of problem diagnosis, research planning, experimentation assessment and dissemination of recommendations (MacDicken *et al.*, 1990):

Diagnosis of the problem: The identification of the psyllid as a serious economic pest demonstrated the existence of "crisis-driven" communications among researchers in many countries. Organizations such as the NFTA and Canadian Undergraduate Service Organization (CUSO) have provided valuable services in publishing updates on psyllid damage and the range of the insect's spread. Leucaena remains one of the most important multipurpose tree species in agroforestry practices in Asia and the Pacific. It follows that any pest which causes significant damage to growth and yield is worthy of serious collaborative research efforts.

Planning for research collaboration: National psyllid research programs began independently in Asia and the Pacific as the infestation reached Australia, Indonesia, Malaysia, the Philippines, Taiwan, Thailand and the United States between 1983-86. This initially led to communication between a few researchers on potential control measures. Notable among these early efforts were introduction of the predatory coccinellid, *Curinus coeruleus*, from Hawaii to Guam, the Commonwealth of the Northern Marianas, Indonesia, Philippines and Thailand. Seed of leucaenas with potential sources of resistance were also exchanged among researchers during these early years.

Beginning in November 1986 a series of international and national workshops were organized to summarize research and develop plan for psyllid research. National objectives and priorities were assembled during a meeting of national psyllid research coordinators in Manila in June 1987. The output from this meeting was a regional plan which summarized the national programs and recommended the support of research in seven general areas (Napompeth *et al.*, 1987). The plan was an important step in identifying researchers and gaps in the range of topics which needed attention.

Experimentation: Virtually all of the research conducted on the leucaena psyllid up to 1988 was funded by national or local sources. Some of this research continues, with current summaries of national program research

projects under preparation for all of the countries involved in the regional program. In 1988, IDRC and USAID began to provide funding to the regional program. Development of studies with support from these two sources was done under direction of national psyllid research coordinators and resulted in a series of projects in Indonesia, Malaysia, Philippines, Republic of China (Taiwan) and Thailand.

Assessment: Assessment of psyllid research has to date been done solely by individual researchers and research institutions. The national psyllid research coordinators and the psyllid advisory group who jointly drafted the regional program for leucaena psyllid research will be the most likely group to evaluate outputs and suggest revisions for the future.

Recommendations and dissemination: To date, recommendations for leucaena producers have come both through national programs and regional meetings. Nearly all of the psyllid-affected countries have produced recommendations of some kind for farmers. Control measures such as spraying, tree species replacement and release of *C. coeruleus* and other natural enemies have been recommended. The two regional scientific meetings on the psyllid (November 1986 in Hawaii and January 1989 in Indonesia) both provided widely-distributed recommendations for leucaena researchers and producers.

Communication and information sharing among national programs in Southeast Asia and parts of the Pacific has been useful to a number of national and international research and development organizations. Some of this exchange, much of it between individual scientists, has already resulted in substantial introduction and provision of biological control agents, and exchange of seed of resistant leucaenas and information on research methods. Recent introductions of another predatory coccinellid, *Olla abdominalis,* and an encyrtid parasite, *Psyllaephagus* sp. nr. *rotundiformis,* from Hawaii to Thailand have resulted in further introductions from Thailand to India, Indonesia and Myanmar.

It is too early to tell how effectively new research results will be shared and communicated. However, efforts by the F/FRED-supported Regional Research Program on Leucaena Psyllid Control and the National Biological Control Research Center (NBCRC) in Thailand, have effectively distributed both information and biological control agents free of charge to interested individuals and institutions.

Tree improvement

Regional projects and networks are best suited to provide support which is beyond the means of individual national programs. Germplasm collections and tree improvement are two such areas. The F/FRED Project has supported seed collection expeditions for *Acacia auriculiformis* and *Acacia mangium* in conjunction with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, Division of Forestry and Forest Products. These collections were successful in providing the first range-wide provenance collection *A. auriculiformis* for use in tree improvement programs. This important collection now serves as the basis for provenance evaluation of *A. auriculiformis* in the humid tropics.

The F/FRED Project is providing support for a series of international provenance trials for *Acacia auriculiformis* to be co-sponsored with the Australian Centre for International Agricultural Research (ACIAR), German Agency for Technical Cooperation (GTZ) and Finnish International Development Agency (FiNNIDA). A total of ten cooperators are participating in the trials, which will evaluate twenty-five provenances of *Acacia auriculiformis*. Data from these provenance trials will be collected by cooperators and entered into the F/FRED Information and Decision Support System data base for analysis by cooperators. Assistance with combined data analysis will also be provided by the Project. In conjunction with these provenance studies, F/FRED and ACIAR have co-sponsored additional research on the inter-specific variation of *Acacia auriculiformis*. These studies have included the establishment of provenance zones, and evaluation of intraspecific variation through glasshouse studies. An annotated bibliography on *A. auriculiformis* is also near completion.

Limited seed production of psyllid-resistant accessions or hybrids of leucaena spp. has been provided through the NFTA to set up a modest seed production system with F/FRED network cooperators in Asia to produce research quantities of promising varieties and hybrids. A collection program for Melia and Azadirachta seed also was initiated in late 1987 with F/FRED support to the Faculty of Forestry, Kasetsart University. Finally, a seed collection and International Provenance Trial series is underway for *Dalbergia sissoo* in India, Nepal and Pakistan.

In early 1989, the Project initiated a regional, multidisciplinary study to determine farmers' preferences for individual tree characteristics. Once identified, these characteristics will describe MPTS ideotypes from a farmers perspective. It is hoped that these ideotypes will help tree breeders determine more relevant criteria for selection and breeding of MPTS. The study is being conducted by sixteen scientists in seven countries.

Regional Study on Farm and Village Forest Use Practices

In early 1989 a Regional Study on Farm and Village Forest Use Practices was initiated. This regional study was designed to determine what variables affect the way villagers obtain, manage and use tree and forest products, and if there are general trends across societies. Of particular interest are the practices of the small farm operators, the landless, and other rural poor. Fourteen researchers from six countries are participating in the study. In addition to support from F/FRED, funding for the study and study-related workshops and meetings is provided by the Ford Foundation/Thailand, the Ford Foundation/Philippines, the GTZ-funded Upper Mahaweli Watershed Management Project, and the FAO Wood Energy Project.

The "independent variables" studied regionwide include general demographic information, agro-ecological information, types of government and non-government development intervention, and land tenure and property. The "dependent variable" is a set of information called forest use practices. The forest use practices being studied are the tree products used by the farm households, the source of those products (from state forest, homestead, farm, commons, purchased), seasonality of use and the species used and preferred.

Each researcher is also exploring a topic of his or her own interest. Each participant is responsible for three distinct outputs from the study: (1) data for comparative analysis in the regional study, (2) a brief descriptive report of each study community to describe selected social and economic variables that are not included in the minimum data set, and (3) a report of publishable quality on a topic selected by the cooperator on farm and village forest and land use practices.

Constraints to network research

The F/FRED Project, like most other projects in an environment of large demands and limited resources, has faced many constraints. This is not intended as a criticism of the Project or the Project designers, but instead points out some limitations that need to be addressed in the second phase.

Focus on limited number of priority MPTS

This constraint was designed into the Project to give it focus. Without limiting the number of MPTS to be researched to a limited number of priority species, it was felt that the depth of research would suffer. However, some researchers continue to seek inclusion of additional species, which tends to dilute this effort. More importantly, however, is the evolution of the Project focus from a species orientation to a problem resolution orientation.

Budget

The budget for the first phase was US$8.9 million for a five-year period in eleven countries and three Project offices. With a Coordinating Unit staff of four full-time professionals, the scope of work includes programs in long and short-term training, small research grants, network trials in three ecological zones, international provenance studies, germplasm collections, regional studies in the social sciences, network committee meetings, international theme meetings, development of research compendiums and publications.

It is not that the funding or staffing is inadequate. As the Project Evaluation Report stated (Butterfield *et al.*, 1988) "Current Phase I funding appears adequate to meet the requirements of F/FRED's implementing contract. However, the current level of funding is inadequate for optimum project success." The current Coordinating Unit staff is spread too thin to do justice to all of the on-going programs and opportunities for additional programs slip away.

Implementation of regional research programs

Constraints to effective regional collaborative research have come from obvious sources: a lack of research funds, differences in research methods and experience and interests of researchers. Competition for scarce research funding remains a problem, even though a series of international meetings have sought to identify means of increasing research funding in the tropics. Establishment of network experiments has been variable largely due to substantial differences in skill and experience levels between participants. In some cases, commitment of participants and institutional support has been inadequate for successful trial establishment and monitoring. The manpower constraints of both the Coordinating Unit and network participants has at times resulted in problems with seed handling and nursery production, data collection and exchange.

A major constraint in increasing the quantity of new regional research on MPTS is the heavy workload of key researchers and substantial differences in the amount of commitment among participants. Those who have been active have contributed substantially to the exchange of knowledge and the spirit of cooperative research. Others have expressed the desire for support and active participation, but have failed to produce or respond to collaborative efforts of other participants.

In addition, limitations in postal, telephone and telex facilities still prevent timely and effective communications in many countries of Asia, although this situation is rapidly changing in countries such as Nepal. Communications facilities and their cost continue to constrain effective "networking" among researchers in Asia.

Yet even with these constraints, the program has been a substantial success in bringing together researchers and programs working on an important common problem.

FUTURE PROSPECTS

Experiences in MPTS network research in recent years has shown that MPTS are important to poor farmers in tropical Asia. The broad range of interest in the MPTS Research network among participating scientists and institutions and the achievements of the network in its first few years of operation suggest that this network is a valuable means of enhancing MPTS research in Asia. Extension of the program for an additional five years as currently planned by USAID would both strengthen the capability of network institutions and possibly help see the evolution of the network from a project-oriented activity into a permanent institution with a broad base of support.

Activities such as short-term training and twinning arrangements between the Faculties of Forestry at Universiti Pertanian Malaysia, Kasetsart University and the University of the Philippines in Los Banos demonstrate the usefulness of regional cooperation. The F/FRED Project and the network have also laid the ground work for the genetic improvement of several promising MPTS which have been might lead to the upgrading of the genetic materials for use in actual planting.

Even though an effort is being made to expand the funding base for network activities, the future prospects for network development remain dependent upon the budget and scope of work for the second phase of the F/FRED Project. As of this writing, this information is not available. The potentials, however, are great for the expansion of on-going programs and the development of new programs. The need to overcome the problems of rural poverty in Asia remains as important as ever. It is imperative that efforts be made to expand and sustain MPTS Research network programs.

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PLANTATIONS INDUSTRIELLES DE PINS AU CONGO: POSSIBILITES ACTUELLES ET PERSPECTIVES DE SYLVICULTURE INTENSIVE

A. MOUTANDA
Ingénieur des Eaux et Forêts
Chef des Programmes Pins
Centre Technique Forestier Tropical, CONGO

FDC: 238: 174.7 Pinus caribaea Morel: (672.4)

SUMMARY

The "Centre Technique Forestier Tropical" has been carrying out since 1959 researches on tropical pines in Congo. It has today a great knowledge in the field of genetic improvment and sylviculture of pine added to a quite important potential in selected vegetal material.

Considering the results obtained concerning the technic of vegetative propagation by cutting of Pinus caribaea, the congolese forestry research is tending today to an intensive sylviculture of pines using vegetal material from controlled pollination. The first results obtained are encouraging and perspectives are promising.

Key words : Pinus caribaea, Industrial plantation, selected vegetal material, intensive sylviculture.

INTRODUCTION

Les reboisements actuels des savanes congolaises sont essentiellement réalisés à partir de trois espèces en ce qui concerne les résineux : Pinus caribaea var hondurensis, Pinus oocarpa et Pinus patula ssp tecunumaii. Ces trois espèces retenues proviennent d'Amérique Centrale. Des résultats très encourageants ont été obtenus pour chacun de ces types d'essence.

En 1979, la technique de bouturage du Pinus caribaea a été mise au point. Son application pratique sur des jeunes arbres issus des pollinisations contrôlées a permis de mettre en place les premières parcelles de boutures de pins qui sont de bien meilleure qualité que les plantations classiques issues des semis.

Le développement de cette technique pourra permettre au Congo

de réaliser dans un avenir relativement proche des plantations clonales dont l'objectif principal est la production du bois de sciage (petit diamètre) et de poteaux support de lignes électriques et téléphoniques.

La présente note a pour objet :

- de présenter brièvement les méthodes sylvicoles utilisées actuellement pour les reboisements en pins des savanes congolaises

- de donner un bref aperçu des possibilités actuelles de réalisation des plantations clonales et de sylviculture intensive en ce qui concerne Pinus caribaea.

CONDITIONS ECOLOGIQUES DES REBOISEMENTS

Les travaux de reboisement s'effectuent sur trois types de savane : les savanes sableuses de la bande cotière de la région de Pointe-Noire, les savanes argileuses de la vallée du Niari et les plateaux batéké situés au Nord de Brazzaville.

Le climat est de type tropical. Il se caractérise par un volume de précipitation très moderé (1200 à 1600 mm) et une hygrometrie élevée. La saison des pluies (Novembre à Octobre)est chaude.La saison sèche (Mai à Octobre)est plus fraîche et nuageuse.

Les sols de la région de Pointe-Noire et des plateaux batéké sont pauvres et ne supportent qu'une maigre couverture de graminées et d'arbustes. Les savanes du Niari sont plus riches.

PLANTATIONS ANCIENNES

Au total plus de 4000 ha ont été plantés entre 1959 et 1980 à l'aide des semis traditionnels. Les graines ont été fournies au début par des marchands européens mais à partir de 1970, elles ont été obtenues en grande majorité à partir des récoltes locales.

Ces plantations étaient destinées initialement à produire du bois de pâte mais à l'heure actuelle, l'objectif d'une grande industrie de pâte chimique s'est revelée trop ambitieux et trop précoce. Ce changement d'objectif s'est traduit par une réduction très sensible des programmes d'extension. Malgré cela, les travaux de suivi se sont poursuivis et le comportement des peuplements existants est resté globalement positif : le rendement des plantations est de l'ordre de 10 à 15 m^3/ha/an à Pointe-Noire et dans les plateaux batéké et de 20 à 25 m^3/ha/an à Loudima.

TECHNIQUES SYLVICOLES EMPLOYEES

Les recherches menées au cours des trois dernières décenies ont principalement porté sur :

- la préparation de terrain

- la pépinière : choix du matériel végétal, type de plant et de conteneur etc...

- les engrais : nature, quantité, date et mode d'apport

- la plantation : période optimale, âge des plants à mettre en place.

- les entretiens

- la conduite des peuplements

- les mycorhizes.

Toutes ces techniques sont actuellement maîtrisées et peuvent être utilisées sans problème par les deux organismes de reboisement : le Service National de Reboisement (SNR) et l'Unité d'Afforestation Industrielle du Congo (UAIC).

Préparation du terrain

Elle est réalisée en saison sèche et consiste à extraire manuellement ou mécaniquement les arbustes avant de procéder au brulage de ces derniers. Le terrain est alors labouré superficiellement à l'aide des charrues à disques trainées par des tracteurs agricoles. Le quadrillage, le piquetage et la trouaison mettent fin aux travaux de préparation de terrain.

Pépinière et plantations

Les plants sont préparés en pépinière soit par la technique de semis en germoir avec repiquage à 6 semaines en pots plastiques soit par bouturage sous chassis des rejets de brachyblaste en petits conteneurs (fertil et pots melfert).

La plantation a lieu au début de la saison des pluies en principe au mois de Novembre. Les plants élevés en sachets plastique sont mis en place après retrait du sac à l'âge d'environ 6 mois.

Les écartements initialement retenus étaient de 2,5 x 2,5 m à Pointe-Noire et 3m x 3m à Loudima mais ces derniers sont passés rapidement à 3,5m x 3,5m sur l'ensemble des stations.

Ces espacements assurent assez rapidement une couverture parfaite du sol et les premières éclaircies ont lieu à l'âge d'environ 7 ans.

E n g r a i s

La fumure utilisée est un engrais complet de type 10.10.20 ou 13.13.21. L'apport d'engrais se fait au trou de plantation à raison de 150 g par plant au moins 3 semaines avant la mise en place.

E n t r e t i e n s

Les entretiens sont réalisés mécaniquement par un pulvériseur à disques (passages croisés) et manuellement (sarclage autour des plants) et durent deux à trois ans. Après cela le peuplement arrive à couvrir parfaitement le sol dès la quatrième année.

C o n d u i t e   d e   p e u p l e m e n t

Les éclaircies débutent généralement à l'âge de 7 ans mais le nombre d'éclaircies et leur intensité ne sont pas encore clairement définis. La recherche a mis en place un certain nombre de dispositifs expérimentaux qui pourront nous permettre de resoudre ce problème au cours des prochaines années.

M y c o r h i z e s

La première introduction de pins au Congo a eu lieu en 1956 mais elle s'est traduite par un échec dû à un manque de mycorhization des plants. L'introduction des plants mycorhizés en provenance du Cameroun a permis de réaliser en 1959 la première parcelle de pin dans la région de Pointe-Noire.

A partir de ces résultats, la pratique courante pour entretenir la mycorhization en pépinière a consisté, pendant plusieurs années, à transporter d'énormes quantités de terre prélevées dans les vieilles plantations de pins afin d'inoculer les jeunes plants en germoir.

Pour améliorer le rendement des plantations, le CTFT-CONGO a réalisé à partir de 1980 un certain nombre d'essais d'introduction de champignons ecto mycorhiziens. Plusieurs souches ont été testées et les résultats les plus intéressants ont été obtenus sur les plants inoculés avec des spores de Pisolithus tinctorius (un gain d'environ 42 % sur la hauteur des arbres).

A partir de ces données les Sociétés de reboisement ont immédiatement   entrepris de remplacer les méthodes traditionnelles

par l'inoculation par simple saupoudrage des plants repiqués avec des spores de Pisolithus tinctorius. Cependant, cette technique qui assure une mycorhization intense et régulière des plants issus des semis rencontre encore de petites difficultés sur les plants de bouture comme nous le verrons par la suite.

PLANTATIONS CLONALES : POSSIBILITES ACTUELLES

La multiplication en masse des plants issus des pollinisations controlées présente à l'heure actuelle une des possibilités de réalisation de plantation clonale. Le bouturage porte essentiellement sur les deux meilleurs croisements HV16 x HB1* et HV12 x HB1* réalisés à l'heure actuelle.

Les résultats acquis par la recherche dans ce domaine ont été mis au service du développement et l'UAIC qui a déjà réalisé 25000 ha de plantations hybrides d'Eucalyptus se propose de relancer les programmes d'extension de pins en vue de diversifier ses débouchés. Interessé par les résultats, cet organisme a décidé de demarrer en 1988 sous le patronage du CTFT-CONGO une petite campagne de bouturage et de plantation semi-industrielle de <u>Pinus caribaea</u>. Cette première parcelle multiclonale ne renferme pas encore des individus sélectionnés au niveau clonal mais le matériel vegetal utilisé est issu d'un croisement contrôlé de qualité nettement supérieure à celle utilisée dans les plantations de semis traditionnels.

Bien que cette expérience soit trop récente pour qu'on puisse en tirer des conclusions, un certain nombre d'essais réalisés antérieurement donnent actuellement des résultats encourageants.

Il existe dès maintenant dans la région de Pointe-Noire de petites parcelles expérimentales de boutures provenant de ces deux meilleurs croisements dont l'âge varie entre 1 et 8 ans. Le comportement actuel de ces peuplements est très satisfaisant et encourage le développement de cette expérience : tous les individus, tout âge confondu, présentent les mêmes caractères de juvenilité que les semis et leur enracinement est tout aussi satisfaisant.

Les superficies plantées se présentent de la manière suivante (en ha) :

1981	1982	1983	1984	1985	1986	1987	1988	Total
2	1,5	2,5	-	1	0,5	3	14,5	25

* Croisement entre arbres + designés sous les indications HB1, HV12, HV16. HB1 est le père de ces deux croisements.

Les mensurations réalisées sur trois parcelles ont donné les résultats suivants :

Numéro de la Parcelle \ Caractéristiques		Hauteur en (m)	Age de la plantation
1981	HV12 x HB1 HV16 x HB1	8,17 9,77	70 mois
1985	HV12 x HB1 HV16 x HB1	4,52 5,48	35 mois
1987	HV12 x HB1 HV16 x HB1	2,55 2,82	18 mois

Le croisement HV16 x HB1 semble mieux se comporter et c'est sur cette famille que l'accent sera mis en priorité en ce qui concerne le choix des clones à multiplier.

D'une manière générale, aucun signe de maladie ou d'attaque d'insecte n'a été observé jusqu'à maintenant sur l'ensemble des peuplements et les arbres ont une croissance tout à fait normale.

Ceci donne simplement de sérieux espoirs quant aux possibilités d'implantation de plantations clonales au Congo.

PERSPECTIVES DE SYLVICULTURE INTENSIVE

Il convient de souligner que la sylviculture des pins au Congo a subi au cours des dernières années moins de bouleversement que celle de l'Eucalyptus.

Cependant l'intérêt porté actuellement par les organismes de reboisement au bois de pin rend pertinente une forte relance du programme de recherche en sylviculture pour cette espèce.

Le matériel végétal obtenu peut permettre de répondre aux demandes à court terme mais une augmentation sensible de la qualité du bois et de la productivité du peuplement doit s'appuyer sur un programme de recherche plus rigoureux et ambitieux.

La sylviculture envisagée consistera donc à réaliser les plantations futures avec des clones selectionnés et à haute

productivité et ce, sur un sol travaillé, fertilisé et peut-être aussi mycorhizé à l'avance puis à soutenir un rythme intensif d'entretiens jusqu'à ce que le peuplement soit fermé.

Pour cela on cherchera à intervenir particulièrement sur les élements ci-après :

- le matériel végétal
- la fertilisation
- la mycorhization
- le transfert de la technique

M a t e r i e l   v e g e t a l

Le matériel végétal utilisé dans les premières plantations multiclonales se compose d'un mélange de boutures de pleins frères. De ce fait, malgré les qualités tout à fait remarquables du matériel employé, les parcelles n'ont pas encore atteint une parfaite homogeneité.

L'objectif actuellement poursuivi est de passer progressivement des peuplements actuels au stade des plantations clonales parfaitement homogènes qui permettraient de faciliter la plupart des problèmes liés à la sylviculture intensive des arbres forestiers : (choix de l'espacement, fertilisation, entretien de la plantation etc...).

Les plantations futures utiliseront donc les meilleurs clones selectionnés dans les meilleures familles issues des pollinisations contrôlées selon le schéma ci-après :

- choix de tête de clones dans les parcelles de semis contenant les croisements contrôlés. L'âge des parcelles devra varier entre 2 et 5 ans du fait qu'à ce stade Pinus caribaea se bouture encore très bien (taux de reussite de l'ordre de 80 %) et que plus tard le bouturage devient difficile.

- multiplication végétative par bouturage de ces clones

- comparaison des clones choisis dans des dispositifs appropriés appelés tests clonaux pour apprécier leurs performances.

- Parallèlement, installation de ces différents clones en parc multiplicatif dans lequel le matériel végétal sera périodiquement recepé et replanté afin de le maintenir dans un état perpetuellement juvenile. A la fin, lorsque les résultats des tests clonaux seront définitivement connus, on multipliera en masse les meilleurs clones conservés à l'état juvenile dans les parcs multiplicatifs pour les besoins des plantations.

A l'heure actuelle un premier test clonal renfermant au total 40 clones a été installé en 1987. Le temps nécessaire entre la sélection du clone à l'état juvenile et son utilisation en plantation est estimé à 8 ou 9 ans compte tenu de ce que nous connaissons sur le comportement de cette espèce dans les conditions écologiques dans la région de Pointe-Noire.

F e r t i l i s a t i o n

Les sols de la région de Pointe-Noire sont pauvres et cela constitue un facteur limitant. On étudiera de nouvelles formules de fertilisation adaptées à un matériel de type nouveau.

M y c o r h i z a t i o n

Les peuplements réalisés à base de bouture devront faire l'objet de nouvelles expérimentations. Les changements intervenus dans les techniques de pépinière à l'UAIC (contraintes industrielles) avec notamment des pots melfert imposent un apport supplementaire de champignon mycorhizien en plantation, là contamination des plants en pépinière s'étant revelée très insuffisante.

En dehors des méthodes d'inoculation en pépinière qu'il faudra renforcer, on pourra envisager le saupoudrage ou l'arrosage d'une suspension de spore dans les trous de plantations quelques semaines avant la mise en place : les plants produits en pots melfert connaissent en effet d'énormes difficultés de démarrage en plantations contrairement aux plants bouturés en sachets plastiques remplis de terre.

T r a n s f e r t-d e- l a t e c h n i q u e

Toutes ces opérations ne pourront être menées avec succès qu'à partir du moment où les nouvelles techniques mises au point seront parfaitement maîtrisées par les organismes de reboisement.

Le CTFT-CONGO collaborera étroitement avec les structures de reboisement pour faciliter au mieux le transfert de ces techniques et les adapter aux conditions industrielles.

CONCLUSIONS

Entreprises depuis 30 ans, les recherches sur les pins au Congo sont parvenues à établir parfaitement les techniques sylvicoles en ce qui concerne les plantations existantes.

Elle s'orientent actuellement vers les plantations clonales qui constituent l'un des objectifs à atteindre. Certes, il est encore trop tôt pour assurer que l'on peut, sans risque,se lancer dans ce domaine mais les resultats déjà obtenus et l'étroite

collaboration qui règne entre la recherche forestière et les organismes chargés du reboisement nous donneront certainement, une fois de plus, beaucoup plus de chance de succès.

Nous collaborerons étroitement avec eux en prévoyant de petits programmes annuels de plantations qui nous fixeront tôt ou tard sur les stratégies à mener.

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International Union of Forestry Research Organisations
(IUFRO)

RECENT AFFORESTATION RESEARCH PROGRESS IN THE AFFORESTATION OF SEMI-ARID AREAS OF TANZANIA

By
L. Nshubemuki
Director of Forest Production Research,
Tanzania Forestry Research Institute, Kibaha, Tanzania

SUMMARY

FDC: 233: (678)

This paper reports on research work on nursery, site preparation, planting, and tending techniques undertaken in Dodoma and to a lesser extent in Malya.

Exotic tree species commonly planted are Eucalyptus camaldulensis Dehn. and Cassia siamea L. Performance, which is evaluated on the basis of survival and height grow is improved by Ploughing and harrowing the site, large pitting; into which 12 month old seedlings raised in 20 cm long polythene tubes are planted in the first rains. Intensive weeding and termite control are mandatory. The implied increases in establishment and tending costs are expected to be offset by returns from coppice sales.

Three activities namely: use of hormones for growth promotion of additional roots assessing the trace element status of the soils in semi-arid Tanzania, and social forestry studies; are recommended for future research.

Key words: Plantation, establishment, tending, hormones, trace elements, social forestry.

RÉSUMÉ

Ce document décrit des travaux de recherche reliés aux pépinières, à la préparatior du site, à la plantation et aux techniques de soins culturaux menés à Dodonia et, dans une moindre mesure, à Malya.

Les espèces d'arbres exotiques communément plantées sont Eucalyptus camaldulensis Dehn. et Cassia siamea L. La performance, évaluée en fonction de la survie et de l croissance en hauteur, peut être améliorée par le labourage et le hersage du terrai de même que par le creusage de gros trous où sont plantés, à l'occasion des premièr pluies, des semis âgés de 12 mois provenant de tube en polythène de 20 cm. Le dégagement intensif et la répression des termites sont absolument nécessaires. Les augmentations inhérentes des coûts d'établissement et de soins culturaux devraient être compensées par les revenus découlant des ventes de taillis.

Les prochaines recherches recommandées devraient porter sur le recours à des hormor comme agents déclencheurs de croissance de racines additionnelles, l'évaluation de l'état des éléments-traces des sols dans la Tanzanie semi-aride et des études en foresterie sociale.

Mots clés: plantation, établissement, soins culturaux, hormones, éléments-traces, foresterie sociale.

INTRODUCTION

Tanzania covers some 887,000 km^2 50 per cent of which is classified under various shades as Semi-arid climate. Three research centres under the aegis of the Tanzania Forestry Research Institute namely: Lake Zone Forestry Research Centre at Malya, the Miombo Woodland Research Centre at Tabora, and the Dodoma Arid Zone Afforestation Research Centre, are at present actively involved in Semi arid afforestation research.

Research work at the Tabora centre is also directed to the ecology of Miombo Woodlands. Research at the other two centres has mainly been focused to the use of exotic tree species for afforestation. One particular problem related to this research work concerns tree species envisaged for afforestation. Should research work be exclusively directed to the use of indigenous tree species as they are believed to be ecologically adapted to the environment, or to exotic tree species? Is the adoption of a mixture a better option than adopting one of these two extremes? An attempt to answer these questions will be made in another paper (Nshubemuki, In preparation). This paper concentrates on the research progress made while using exotics.

Location of trial sites

Malya trials are located in Igwata Forest Reserve Longitude 33°30' - 33° 31'E; and Latitude 2° 56' - 2° 58'S. Long term annual rainfall varies from 480 - 630 mm. However, annual amounts as high as 800 mm have been recorded.

Dodoma trials are concentrated in Dodoma District, longitude 35° 06' - 36° 06' ; and Latitude 5° 30' - 7° 30'S. Mean annual rainfall varies from 450 - 550 mm.

Additional information about climate, geology, soils and vegetation is found in Sabas and Nshubemuki (1988), and Nshubemuki and Maphole (1984).

The Problem

The trials that were established in Dodoma in the early, mid and late 1970's concentrated on species, and to a lesser extent on eucalypts provenance trial. The performance of these trials has been reported by Malimbwi (1978), Mushi (1981), and Nshubemuki (In press). Earlier trials at Malya (Anon. 1964) were exclusively species trials. Further trials at Malya (Sabas, 1985) involved provenance trials.

As tree survival in areas of marginal rainfall depends among other things, on nursery, site preparation, planting and tending techniques; there was need to correct the imbalance of emphasis evident in the work initiated earlier. The experimental material was oftenly *Cassia siamea* and *Eucalyptus camaldulensis* for they are widely planted exotics in semi-arid Tanzania.

METHODS

The techniques used to raise plants in Dodoma and Malya nurseries are described by Nshubemuki (In, press) and Sabas and

Preplanting operations included grass clearing and burning, pitting oftenly at 2.5m x 2.5m espacement. Pit size was oftenly 30cm x 30cm x 30cm. Complete Randomized Block, and occasionally Factorial Experimental Designs were used.

Subsequent tending operations included slashing (once annually for Dodoma trials), strip weeding (thrice annually for Malya trials), clearing of firelines and general protection.

Survival percentages and total height were recorded from all trees. Analysis of variance was undertaken for mean height, while that for mean survival was after angular transformation of the data.

RESULTS

(a) Plant Production Trials

Pot sizes

A pot size experiment indicated a positive correlation between tube size and plant survival. Differences were still noted 18 months later. Bare rooted, and plants raised in 10 cm long tubes were significantly different from those raised in longer tubes (Table 1). Differences in height growth were not significant.

Table 1. Influence of tube length and the performance of 18 month old Cassia siamea at Nkurugano, Dodoma, Tanzania.

Length of tube (cm)	Seedling Survival (%)* at: 6**	18	Performance Mean height (m) at: 6	18
Bare rooted plants	0	0	0	0
10	42	12.65	0.23	0.36
15	60	29.88	0.37	0.60
20	73	36,66	0.44	0.57
25	84	50.41	0.55	0.98

* Data transformed   LSD p ∠ 0.05 = 25.50 %
** Months

Age of planting stock

Following a dry spell that ensued after planting out many blocks in the age of planting stock experiment dried. However, it seems that the stock kept in the nursery for at least 12 months performs better than young planting stock (Table 2).

Table 2. Influence of size (age) to the performance of 18 month old Eucalyptus camaldulensis plantings at Nkurugano, Dodoma, Tanzania.

Age of planting stock (months)	Mean Survival (%)	Mean Height (m)
2	0.0	0.0
4	12.8	0.2
6	1.6	0.1
8	28.8	0.4
10	39.2	0.3
12	36.0	0.5

Interaction of planting stock size (age), length of polythene tube and time of planting.

Analysis of variance for individual factors of a 3x3x2 factorial experiment revealed that differences in the time of planting, age of planting stock, and length of polythene tube significantly influence the performance of 18 month old *Eucalyptus camaldulensis* plantings.

Table 3 shows that the best survival was achieved by carrying out early planting with 12 month old stock raised in 20cm tubes. Planting eight and 12 month old stock generally produced significantly better results than planting with four month old stock. Mid planting of 12 month old stock in 20 cm tubes was also significantly good. Late planting significantly affected the survival of *E. camaldulensis*.

Table 3. Influence of planting stock age, length of polythene tubes, and planting season to survival (%) and height growth (m) of 18 month old *E. camaldulensis* plantings at Mkuruganzo, Dodoma, Tanzania.

	EP*						MP					
	A4		A8		A12		A4		A8		A12	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_{22}	L_1	L_2	L_1	L_2
%	31fg	27g	35f	55b	57b	63a	33f	48cd	50c	39e	46d	58b
	LP											
	A4		A8		A12							
	L_1	L_2	L_1	L_2	L_1	L_2						
%	40e	40e	30g	46d	52bc	40e						

* EP, MP, & LP Respectively mean: early, mid and late planting

A4, A8, & A12 Mean 4, 8, and 12 month old planting stock respectively.

L_1, & L_2 Mean 10 and 20 cm long polythene tubes respectively.

LSD $p < 0.05$ = 3.%.

Height growth is influenced by individual factors - age of planting stock and length of planting tube. The planting season seems to have no influence on height growth, and neither do any of the possible interactions of the three factors.

Table 4 indicates that the means for four, eight and twelve month old planting stock are distinguishable. Similarly, the mean heights of plants grown in the two pot sizes are also distinguishable. This suggests that twelve month old plants raised in 20 cm tubes best influence height growth in Eucalyptus camaldulensis.

Table 4. Influence of age of planting stock and pot size on height growth of Eucalyptus camaldulensis at Nkurugano, Dodoma, Tanzania.

	Age of planting stock (months)			pot size (cm)	
	4	8	12	10	20
Mean height growth (m)	2.2c	2.8b	3.8a	3.9 b	5.0 a

LSD $p < 0.05 = 0.12m$ LSD $p < 0.05 = 0.10m$

(b) Site Preparation Trials.

A site preparation experiment replicated four times in Dodoma District indicated no significant differences between the sites. However, there were significant differences between the treatments. Table 5 indicates that ploughing and harrowing is the most effective method for promoting survival of E. camaldulensis. Manual methods of site preparation proved to be the most inferior, whereas all other identified methods had results which are rather indistinguishable.

Table 5. Mean survival (%) of 18 month old E. camaldulensis as influenced by site preparation methods in Dodoma District, Tanzania.

Site Preparation Method	Manual	Ridging	Sub-soiling	Ploughing	Ploughing & Harrowing
Mean survival (%)	16.34	44.63	37.67	39.06	59.35

LSD $p < 0.05$ = 10%

Pit Sizes.

Investigations into the influence of pit size and other planting site preparation techniques did not show significant treatments between treatments. However, plant survival seemed to be somewhat increased by the treatments (Table).

Table 6. Influence of various pit sizes on survival (untransformed) and height growth of indicated 3.5 year old tree species at indicated sites in Dodoma, Tanzania.

Site	Species	Pit size	Mean Survival (%)	Mean Height (m)
Chimwaga	*Cassia siamea*	a*	84	2.09
		b	82	2.19
		c	60	3.15
		d	81	2.46
		e	74	1.92
Mlebe	*E. camaldulensis*	a	51	3.43
		b	82	3.19
		c	64	3.24
		d	58	2.55
		e	70	3.63
Nkurugano	*C. siamea*	a	54	1.05
		b	68	1.42
		c	61	1.13
		d	56	1.65
		e	79	1.32

* Pit size (cm) width x depth respectively: 15x30, 15x30 with saucers, 30x40, 30x40 with saucers, 15x30 with trenches and ridges.

(e) Planting, and Tending Techniques

Time of planting

Assessments for planting dates for both the Dodoma and Malya experiments did not reveal significant differences (Table 7), for the Dodoma plantings significant differences were noted for Malya plantings but survival was too low to justify meaningful conclusions.

Table 7. Effect of planting dates on survival (untransformed) and height growth of indicated tree species at various sites in Tanzania.

Location (site)	Age (yrs)	Planting date	*Casia siamea* S(%)	*Casia siamea* H(m)	*E. camaldulensis* S	*E. camaldulensis* H	*E. citriodora* S	*E. citriodora* H	*E. microtheca* S	*E. microtheca* H
		a*	47	1.02	75	0.88	6	0.61	70	0.60
Dodoma	1.5	b	85	1.14	87	1.10	30	0.58	60	0.53
(Nkurugano)		c	32	1.33	85	1.03	30	0.63	85	0.56
		d	65	1.08	89	1.00	52	0.70	63	0.55
		First rains			33	3.90				
Malya		17 days later			15	5.10				
(Igwata)		34 days later			19	3.72				
		60 days later			12	3.84				

*Planting dates respectively: First rains, 14, 42, and 56 days later. S, and H respectively denote mean for: Survival (%) and Height growth (m).

Termite control and weeding trials:

Evaluation of termite control trials in Dodoma and Malya is in progress (Kisaka *et al*; In Preparation). Sabas and Kalaghe (1986) reported on weeding trials at Malya. It was observed that clean weeding best promotes survival, height and diameter growth in *E. camaldulensis* although it is not significantly different from 1 metre wide strip weeding. Furthermore, 1 metre wide spot weeding alone was as effective as combined spot weeding and slashing, while slashing alone significalntly lowered survival, height and diameter growth.

DISCUSSION

Although rainfall failures in Semi-arid Tanzania are not more frequent than successes, rainfall reliability is by definition low. The weather conditions obtaining immediately after planting out influenced the performance of the trials. Because other preconditions for success such as suitable site preparation methods were unknown. The results should therefore be interpreted in that background.

Viewed singly (Table 1, and 2) or in combination (Table 3, and 4), plant production trials emphasize the need of raising *E. camaldulensis* and *C. siamea* (and most likely other tree species) in 20 cm long polythene tubes for 12 months and planting the stock during the first rains. Early planting however, is not always trouble free. Table 7 shows somewhat impressive survivals for some of the stock that was planted late. Given suitable site preparation techniques notably ploughing and harrowing (Table 5), early planting is a more convincing strategy than the risk prone late planting. Moreover, observations on village plantations of 21 and 40 hectares at Nkhome and Chamwino respectively (in Dodoma District) indicate that ploughing the site a year before it is planted and reworking the soil just before planting, tends to promote tree survival and height growth. Similar results have been obtained in in Northern Nigeria by Iyamabo and Ojo (1972). Essentially, these establishment techniques are a large scale use of increased pit size (Table 6).

The above findings including termite control and intensive weeding needs, imply increased plantation establishment and tending costs. As it is expected that most plantations in Semi-arid Tanzania will be managed by the coppice system, it is possible that revenues accrued from coppice sales may offset initial establishment and tending costs.

Three major activities are envisaged for future research. These include: Experimenting on the use of solutions of auxins and gibberellins. These are known to stimulate the emergence of additional roots (Nowak and Lawson, 1983). It is therefore possible to maximise growth in the short growing season. The fast growth advocated imply rapid cell division and increased water needs. Studies on the availability of trace elements notably boron that influences these activities will have to be undertaken much as it is important to establish the trace element status of the soils in Semi-arid Tanzania. The role of zinc in contributing to aridity in Western Australia, probably has its similarities in other tropical areas.

The success of many rural development projects depends among other factors, on the participation of the people. Thus plantation establishment techniques reported in this paper were tailoired in such a way that the results can be easily transfered to the users. Therefore, social forestry studies need be increased. This seemingly broad study can be trimmed down into a series of research topics resulting from a list of problems reported as commonly experienced by the foresters working in semi-arid Tanzania. Such a list is likely to assist in the identification of pressing problems and the implied research emphasis.

ACKNOWLEDGEMENTS

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TREE ARCHITECTURE AND INCREMENT ANALYSIS AS ORIENTATION FOR SILVICULTURE IN THE TROPICS

Rudi Arno Seitz

Professor of Silviculture
Department of Silviculture and
Forest Management
Universidade Federal do Paraná, Brazil

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SUMMARY

An analysis of tree architecture is made, according to its consequences for the silviculture in tropical regions. It can be demonstrated, that there are strong correlations between crown characteristics and trunk radial increment. Therefore, for higher increments more space is needed. But if there is enough space, each tree species develops its crown according an endogeneous architectural model, which in many cases is not desired by the foresters. A momentarily suppression of the natural model means lower increments, but higher quality of the logs.

Keywords: architectural analysis, tropical silviculture, radial increments

INTRODUCTION

Any forester who enters a tropical forest is delighted by the straight trunks of the trees and some of its dimensions, both in diameter as in height. The next thought is the replication of those trunks, but now in greater number and only for those species which have a commercial value, by silvicultural treatments of the tropical forests. It seemed that the fastest way to get this was by planting of pure stands of the desired species. But soon, fast growth with poor stem quality or very slow growth (and survival) showed that silviculture in plantations for high quality wood production is very difficult, and also the silvicultural treatments of forests are not easy. For sound silviculture in tropical forests, more attention to the differences between tree architecture and some basic concepts of tree growth must be given.

THE TREE ARCHITECTURE

Trees have in general well defined growth patterns, characteristic for each species, which leads to specific architecture of the crowns (HALLÉ et al.,1978). Those distinct growth patterns are ecological adaptions to the environment, and represent the best compromise between the physiological characteristics of the species and the environment.

In their work about tree architecture, HALLÉ et al.(1978) describe many architectural models of tropical trees, and give some ecological interpretation for each one. Here it is important to discuss the principal elements of tree architecture, which we need for our silvicultural interpretation. Two elements have a key role: the differemtiation of meristems in sexual or vegetative meristems, and the differentiation of direction of growth (orthotrpy vs. plagiotropy) of the meristems. Combined with rhythmic or continuous growth, reversible or irreversible plagiotropy and the capability of reiteration of the model, those two elements are present in every architectural tree model, and are the basis for the silvicultural treatment of the forests.

For example, if a tree have an orthotropic meristem, with plagiotropic branching meristems, the development of a straight trunk is the basis for the model (MASSART's model). But in other models, although there are still othotropic meristems, they are on equivalent modules produced at the same time, and for a straight trunk, one of the modules needs to become clearly vertical, beeing the basis for a next set of modules (KORIBA's model). Even if all the meristems are plagiotropic, the continual superposition of branches can lead to a nearly straight trunk, if the environment is unfavourable for the specific model (TROLL's model). The three models are schematically represented in fig.1.

When the apical meristems change from vegetative to sexual, producing terminal flowers or inflorescences, automatically lateral meristems develop, producing branches. For the development of a straight trunk therefore we need to delay this change as far as possible, or suppress branch growth, trying to obtain again an apical vegetative meristem from one orthotropic or even reversible plagiotropic branch meristem.

In other trees, like *Arcucaria angustifolia* (MASSART's model), although there are a vegetative apical meristem, and the sexual meristems are on branches higher order, but combined with an irreversible plagiotropic branch meristem, the loss of the apical vegetative meristem can not be replaced by one branch meristem. Therefore, for straight trunks, a reiteration must be originated by dormant meristems from the main axis (SEITZ,1986).

Height growth of trees in the forest is therefore a continuous struggle between the endogeneous directions of meristem growth and the environmental conditions combined with casual injuries through animals, insects, falling limbs, etc..

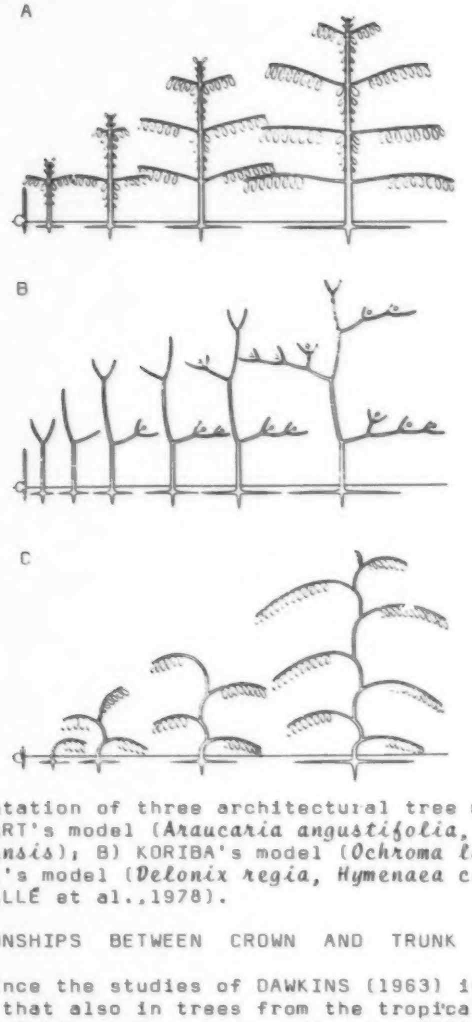


Fig.1 - Representation of three architectural tree models: A) MASSART's model (*Araucaria angustifolia*, *Virola surinamensis*); B) KORIBA's model (*Ochroma lagopus*); C) TROLL's model (*Delonix regia*, *Hymenaea courbaril*) (from HALLÉ et al.,1978).

RELATIONSHIPS BETWEEN CROWN AND TRUNK

At least since the studies of DAWKINS (1963) in Africa it should be clear that also in trees from the tropical forest there is a strong correlation between crown diameter (CD) and trunk diameter (DBH). In his research, DAWKINS could demonstrate a straight linear regression in every of the 12 species measured. In some cases, like with the species *Triplochiton sp.*, the relationship holds in different environments, as open grown or under shelter growing trees. A comparison of those regression coefficients with the architectural models, can't show any grouping at this moment (Tab.1).

Table 1 - Coefficients of the regression function CD = a + b.DBH for 12 forest tree species (from DAWKINS,1963) and the corresponding architectural models (HALLÉ et al. 1978)

Tree species	Coefficients [1)] a	b	Model
Aucoumea klaineana	0.9	0.180	RAUH
Byrsonima spicata	0.5	0.235	AUBRÉVILLE
Dacryoides excelsa	1.5	0.160	RAUH
Dydimopanax morototoni	1.0	0.220	LEEUWENBERG
Manilkara nitida	1.5	0.170	AUBRÉVILLE
Ochroma lagopus	0.7	0.205	KORIBA
Swietenia macrophylla	0.4	0.190	RAUH
Terminalia ivorensis	1.2	0.230	AUBRÉVILLE
Terminalia obovata	2.0	0.200	

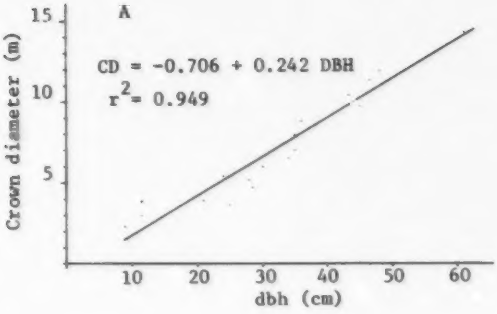
1) for CD in m and DBH in cm

The same straight relationship can be observed in *Araucaria angustifolia* in southern Brazil (Fig.2 A). And here, because of the well defined branching pattern (MASSART's model), also a strong correlation exist between branch lenght and branch diameter (Fig.2 B). This means that for a trunk with great diameter the three needs a corresponding broad crown, and branches with great diameter. Or in other words, growing space (SEITZ, 1986).

But for logs with high quality, branches (and dead knots) should be as narrow as possible. At least in the first logs of the trunk. In its natural environment, *Araucaria angustifolia* seems to have a good self pruning, with natural suppression of the branches. A detailed stem analysis however shows that this is only possible if the branches are very thin. Consequently, also the annual diameter increment is low, if compared with a tree of the same species, but in a plantation, with less competition in the first years (Fig.3).

INFLUENCE OF ENVIRONMENT ON SECONDARY GROWTH

As discussed before, the architectural model of a tree is the morphological expression of its genotype. And the genotype has some common features for all the individuals of a specieas, according the role of this species in the ecosystem. In their description of the architectural models, HALLÉ et al.(1978) show clearly the ecological importance of each model. BOOJH & RAMAKRISHNAN (1982) found a higher bifurcation ratio in early successional tree species.



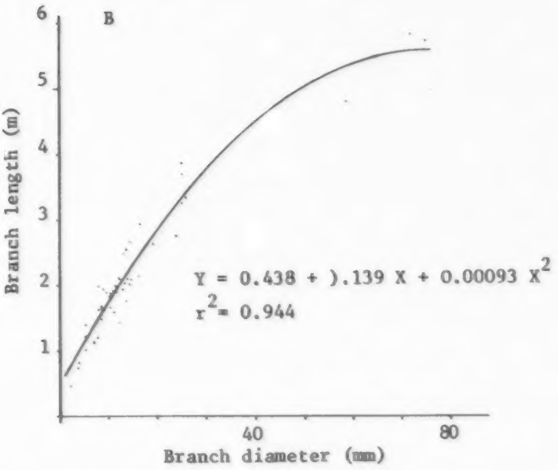


Fig. 2 - Relationships between crown diameter and dbh (A) and branch lenght and diameter (B) in *Araucaria angustifolia* in southern Brazil.

But the bifurcation ratio can change with variations in light environments where the tree grows (BOOJH and RAMAKRISHNAN, 1982). Light seems to be the main environmental factor for the development of the architectural model. In the natural forest sometimes it is difficult to discern between light influences and other site factors, like nutrients. If a tree has good light and site conditions, it can develop more branches, and therefore higher dbh increments (Tab.2), than trees growing under poor light and soil conditions, as showed by WORBES(1989) for *Tabebuia barbata*.

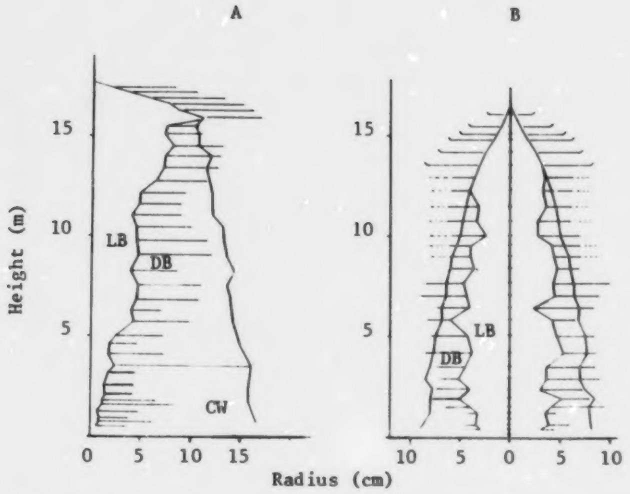


Fig. 3 - Whole stem analysis of *Araucaria angustifolia*, showing the live branch zone (LB), dead branch zone (DB) and clearwood zone (CW). A - tree 60 years old, natural forest; B - tree 18 years old, plantation (2.500 trees/ha).

Tab. 2 - Radial growth per year of trees in the tropical forest of India, according to the environment (from BOOJH and RAMAKRISHNAN, 1982).

Species	Radial growth (cm/year) open	forest
Quercus dealbata	0.55	0.27
Quercus griffithii	0.42	0.25
Machilus kingii	0.49	0.20

Better comparisons can be done in plantations on the same site, but with or without shade. If *Cordia alliodora* is open grown, the tree develop its architectural model (MASSART), with many thick branches inserted in an angle of 45^{o} (orthotropic) to the trunk (YARED et al., 1980). But on the same site, under a light shelter, the trees had branches with a higher insertion angle and were thiner. Similar results were achieved by ALENCAR et al.(1981), working with plantations of *Calophyllum angulare* near Manaus (Tab. 3). Here the shade had a negative effect on trunk quality, but again, increment and diameter of branches were higher in full light, compared with the shaded trees.

Table 3 - Growth of *Calophyllum angulare* in plantations near Manaus, in full light and under shelter (ALENCAR et al. 1981)

Age (years)	DBH (cm)	MAI (mm)	Light
5	6.6	13.2	full
15	15.3	10.2	full
7	2.0	2.8	shade
13	7.3	5.6	shade
14	5.9	4.2	shade

EFFECTS OF SILVICULTURAL TREATMENTS

It is well known that thinnings improve the radial growth of the remaining trees in the forest. And thinnings frome above have normally more effect than from below, if the same number of trees were removed. This shows clearly that by improving the crown development of a tree, it can also be improved the growth of the trunk.

Analysing the growth reaction of araucarias after releasing from the overstory, NOGUEIRA(1989) found clear relationships between crown features and radial increments of the trunk(Tab.4). The increments were higher on trees with a hemispherical crown shape, than on trees with flat or even bowl type crowns (Tab. 5). And since the analysis were conducted in areas which were treated 10, 20 and 35 years earlier, an increasing number of crown features were important for discriminating the tree crown types and therefore the increment after releasing.

Tab.4 - Crown characteristics of *Araucaria angustifolia* correlated with radial increment of the trunk and important for discriminating crown types, after three periods of releasing (NOGUEIRA, 1989)

Years since the crown releasing		
10	20	35
- distance between pseudowhorls	- % of crown - crowndiameter - number of green branches - number of pseudowhorls - h/dbh ratio - mean diameter of green branches	- % of crown - crowndiameter - h/dbh ratio - number of pseudowhorls - distance between pseudowhorls - mean diameter of green branches

Tab. 5 - Mean annual radial increment of *Araucaria angustifolia* during 10 years before (B) and in the periods after (A) crown releasing, according to the crown types (NOGUEIRA, 1989).

Crown type	Years after releasing 10		20		30	
	MAI (mm/year)					
	B	A	B	A	B	A
	1.67	3.73	0.86	4.20	0.83	3.31
	0.72	2.66	1.73	3.96	1.30	2.82
			0.70	1.99		

CONCLUSIONS

Silviculture in tropical forests is an action upon a great number of different trees, each one with its special growth habitus and ecological constraints. Clear is that for fast diameter growth of the trunk, also the crown needs space for fast development. And as shown before, there are different architectural models for each tree species. Some of them produce a straight trunk only as a consequence of constraints of the environment, which normally also are constraints for fast growth.

In general terms, radial increment of tropical trees in their natural environment is very low. Even o species with great crowns, as can be seen in the analysis of MORAES (1970). *Parkia pendula* is a tree with broad crowns as an emergent tree, but not so far, the annual radial increment, 4.1 mm on a trunk with 96.4 cm DBH, seems very low, if compared with increments of other tree species in plantations.(Tab.6).

All increment studies with tropical trees indicate that silviculture in tropical regions deals with slow growing trees. To achieve high wood quality in the trunk, the forester needs to supress momentarily the endogeneous tree architecture, or prune the trees for branch control. Some species, with monopodial trunks like *Terminalia ivorensis* or *Swietenia macrophylla* may be even planted in pure stands, but then although the better increments, more attention must be directed on branching.

On the other side, the planting of trees in mixed stands, or in the secondary degraded forest, seems better for the trunk quality, but the radial increments are lower. Trees with plagiotropic axes need the lateral pressure for straight trunks, as

Tab. 6 - Radial annual increment of some tropical trees, according to diameter classes, near Belém, Bra_il (from MORAES, 1970).

Species	DBH (cm)	Radial increment (mm/year)
Voucapoua americana	11.8	3.7
	25.5	4.6
	33.7	2.9
Piptadenia suaveolens	10.8	0.7
	23.9	1.7
	34.4	1.2
Parkia pendula	10.2	6.2
	43.3	7.9
	96.4	4.1
Theobroma subincanum	9.9	3.7
	10.2	2.8
	26.4	2.2
Dialium guianensis	13.7	1.0
	26.7	1.8
	29.6	1.1

can be demonstrated with *Enterolobium contortisiliquum* in the tropical forest of the Paraná River. But this again means lower increments. Therefore, silviculture with tropical trees, or in the tropical forest, is a long term activity, if high quality wood is the aim of the production.

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RECHERCHES SUR *ACACIA MANGIUM* WILLD.[1] ESPECE DE PLANTATION D'AVENIR, EN ZONES TROPICALES HUMIDES D'AFRIQUE CENTRALE ET OCCIDENTALE

Oudara Souvannavong

Centre Technique Forestier Tropical
Département du CIRAD
94736 Nogent-sur-Marne Cédex, France

FDC: 238: 176.1 Acacia mangium Willd.: (213)

SUMMARY

First planted as an exotic in Sabah (Malaysia) in 1966, *Acacia mangium* has become one of the most popular plantation species in the lowland humid tropics because of its rapid growth and ability to colonize degraded lands in relation with its nitrogen fixation capacity. The species was first introduced in Ivory Coast in 1980. Research work have been undertaken since in various fields, in Ivory Coast, Cameroon, Benin and Congo.

Silvicultural research has resulted in spacing recommandations and growth models for different site qualities, as well as cutting rooting techniques.

Provenance selection has led to establishment of seed stands of good origins thus widening the initially narrow genetic base

Acacia mangium - Rhizobium symbiosis studies are undertaken in cooperation with a laboratory in France. They aim at improving both the bacteria and the host plant. Micropropagation techniques have been developped to allow early clonal selection. Few interesting strains and clones have already been selected and are being tested in field trials.

INTRODUCTION

Acacia mangium est originaire de régions tropicales humides de basse altitude s'étendant entre 1° et 18° de latitude Sud sur les Iles Moluques, le Sud de la Nouvelle Guinée et le Nord-Est de l'Australie (Turnbull et al. 1983). C'est un grand arbre pouvant atteindre 30 m de haut et 60 cm de diamètre.

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[1]Désigné actuellement selon la nouvelle classification botanique sous le nom de *Racosperma mangium* (Willd.) Pedley (Pedley 1986).

Son utilisation en plantation a débuté en 1966, au Sabah (Malaisie), pour la réalisation de pare-feu. Sa forte croissance et sa capacité à recoloniser des zones dégradées en ont rapidement fait une des espèces favorites de plantation au Sabah (Udarbe et Hepburn 1986) et dans d'autres régions.

Acacia mangium a été introduit pour la première fois en Afrique occidentale en 1980, dans le Sud-Ouest de la Côte d'Ivoire, en zone de forêt dense sempervirente. L'espèce confirme ces potentialités dans ce nouveau milieu où elle présente un intérêt pour la production de bois combustible et la restauration de la fertilité des terres agricoles dégradées en relation avec sa capacité à fixer l'azote atmosphérique.

Des travaux sont menés depuis 1984 également au Cameroun, au Congo et au Bénin dans les domaines de la sylviculture, de la sélection de provenances et de l'amélioration de la fixation d'azote en relation avec le laboratoire de Biotechnologie des Systèmes Symbiotiques Forestiers Tropicaux (BSSFT) situé à Nogent-sur-Marne (France).

Sont exposés ci-dessous les principaux résultats acquis dans ces différents domaines, ainsi que les observations faites concernant les aspects phytosanitaires.

SYLVICULTURE ET PRODUCTION

Les travaux ont été réalisés en Côte d'Ivoire pour l'essentiel (Dupuy et N'Guessan 1990). Ils portent sur l'écartement à la plantation, la croissance et la productivité, le recépage pour la conduite en taillis et enfin, le bouturage.

Ecartement à la Plantation

Une des premières parcelles mises en place, en 1980, à San Pedro dans le Sud-Ouest de la Côte d'Ivoire, est un essai comparant trois écartements de plantation : 4 m x 2 m, 4 m x 3 m et 4 m x 4 m (Offi 1988). Un autre essai a été établi en 1985 à Anguédédou, dans le Sud Est du pays en milieu moins favorable (anciennes jachères agricoles sur sols sableux), avec des écartements de 2.5 m x 2.5 m, 3 m x 3 m, 3 m x 4 m et 4 m x 4 m. Les résultats de ces essais figurent dans le tableau 1.

L'influence de l'écartement sur l'accroissement en circonférence est sensible dès l'âge de 3 ans. L'écartement 3 m x 3 m (ou 4 m x 2 m) semble être le meilleur compromis pour une bonne productivité des parcelles et une bonne croissance individuelle des tiges permettent d'atteindre le diamètre d'exploitabilité assez rapidement.

Tableau 1: Résultats d'essais écartement mis en place en Côte d'Ivoire. D'après (Offi 1988) et (Dupuy et N'Guessan 1990)

Essai	Ecartement à la plantation	Age (années)	Circonférence moyenne (cm)	Volume (m³/ha)
San Pedro (1980)	4 m x 2 m	3.5	35.2	110
		7	42.9	246
	4 m x 3 m	3.5	40.6	83
		7	49.9	190
	4 m x 4 m	3.5	40.6	84
		7	53.4	182
Anguédédou (1985)	2.5 m x 2.5 m	2	18.1	16
		3	28.0	67
		4	32.6	95
	3 m x 3 m	2	19.5	18
		3	29.8	78
		4	34.8	92
	3 m x 4 m	2	20.3	13
		3	32.7	63
		4	40.8	93
	4 m x 4	2	20.3	9
		3	34.6	43
		4	43.2	74

Modèle de Croissance

Un modèle de croissance a été élaboré pour l'*Acacia mangium* à partir de 60 placettes dont l'âge est compris entre 2 et 8 ans. L'écartement à la plantation est de 3 m x 3 m. Quatre classes de fertilité ont été distinguées en fonction de la hauteur dominante :

Tableau 2: Classes de fertilité en Côte d'Ivoire

Classe de fertilité	1	2	3	4
Age d'exploitabilité (ans)	6	7	8	9
Hauteur dominante (m)	23.1	21.6	19.4	16.5
Diamètre moyen (cm)	18	17	16	15
Accroissement moyen en volume (m³/ha/an)	35	26	19	12

Les âges d'exploitabilité sont compris entre 6 et 9 ans. La production varie entre 110 m³/ha et 210 m³/ha pour un diamètre d'exploitabilité compris entre 15 cm et 18 cm.

E t u d e d u R e c é p a g e

L'objet de ces études est d'évaluer la capacité à rejeter de souches de l'*Acacia mangium* ainsi que les modalités optimales de recépage en vue de la conduite des parcelles en taillis. Elles ont été réalisées dans le Sud-Est de la Côte d'Ivoire (Dupuy et N'Guessan 1990).

Différents aspects sont à envisager :
- la date de recépage,
- la hauteur de recépage,
- l'âge du recépage (qui n'a pas encore été étudié).

Date de recépage

Le peuplement étudié était âgé de deux ans. Le diamètre moyen des arbres était de 9 cm. Le recépage a été réalisé à 0,5 m de hauteur. En fonction du régime des pluies, quatre dates de recépage ont été testées :
- fin de saison sèche (mars)
- début de saison des pluies (juin)
- milieu de saison des pluies (septembre)
- début de saison sèche (décembre)

Tableau 3: Evolution du % de souches vivantes en fonction de l'époque de recépage

Délai après recépage	Mars	Juin	Septembre	Décembre
6 mois	97 %	93 %	16 %	16 %
1,5 an	87 %	61 %	9 %	12 %

Il faut donc recéper en fin de saison sèche. Deux ans après le recépage, le nombre de rejets vivants varie de 3 à 7 selon les traitements, ils atteignent 9 cm de diamètre moyen.

Hauteur de recépage

Trois hauteurs de recépage ont été essayées pour définir l'optimum de hauteur à préconiser :
- rez de terre
- 0,25 m
- 0,50 m

Le peuplement recépé était âgé de 4 ans, avec un diamètre moyen de 11 cm et une densité de plantation de 1 600 tiges/ha. Il a été recépé fin mars soit en fin de saison sèche qui est la période la plus favorable pour le recépage.

Tableau 4: Evolution du % de souches vivantes en fonction de la hauteur de recépage

Délai après recépage	rez-terre	0,25 m	0,50 m
1 mois	29 %	87 %	97 %
5 mois	3 %	46 %	62 %

Il faut donc recéper à une hauteur d'au moins 0,25 m au-dessus du sol pour obtenir un taux de survie des souches acceptable.

B o u t u r a g e

L'étude du bouturage d'*Acacia mangium* a déjà été réalisée sur de jeunes semis de 2 mois (Wong 1988). Des essais ont été effectués au Congo avec du matériel âgé de 3 ans (Charles 1989). On a adapté à l'*Acacia mangium* les méthodes utilisées depuis 12 ans pour le bouturage industriel de clones d'Eucalyptus hybrides hautement performants : enracinement sous brumisation diurne pendant 20 à 25 jours avec 60 % d'ombrage durant les 3 premiers jours, sevrage par réduction progressive de la brumisation. Le substrat utilisé est une terre sableuse très filtrante.

L'étude a porté sur un total de 235 souches de diamètre compris entre 3 et 25 cm.

Les principaux résultats sont les suivants :

. La période optimale pour le recépage est la fin de la saison sèche ou au début de la saison des pluies.

. La hauteur optimale de recépage est de 30 à 40 cm.

. Le nombre de rejets par souche est très variable, mais n'est pas directement lié au diamètre. On obtient en général de 20 à 40 rejets par souche.

. La récolte des boutures peut avoir lieu entre 40 à 50 jours après la coupe. L'enracinement est très difficile pour des boutures prélevées au-delà de 90 jours après le recépage.

. L'enracinement en fonction de la position de la bouture n'a pas été étudié, mais la taille des boutures (de 2 à 6 noeuds) semble avoir peu d'effet.

. L'hormone utilisée est l'AIB. Les effets des concentrations testées (de 0,4 à 1 %) ne sont pas significativement différents.

Ces techniques ont été utilisées en Côte d'Ivoire pour la multiplication végétative d'arbres sélectionnés âgés de 3 à 5 ans, avec un taux d'enracinement de 87 % (Kadio CTFT Côte d'Ivoire, communication personnelle).

SELECTION DE PROVENANCES

Les premières parcelles d'*Acacia mangium* de Côte d'Ivoire sont issues de graines introduites du Sabah dont tous les peuplements étaient eux-mêmes à l'époque probablement issus par générations successives, d'un seul lot de graines récoltées sur un arbre en Australie (Sim 1984). Si les plantations d'*Acacia mangium* doivent se développer de manière importante, il serait risqué, à long terme, de se reposer sur une base génétique aussi étroite. Suite aux prospections effectuées en 1980 et 1982 dans l'aire naturelle en Indonésie, en Papouasie Nouvelle Guinée et en Australie (Doran et Skelton 1982 ; Turnbull et al. 1983), des essais internationaux de provenances ont pu être réalisés.

Des essais ont été mis en place en 1984 au Cameroun (Bibani 1985), au Congo (Diangana 1987) et en Côte d'Ivoire (Offi 1988 ; Dupuy et N'Guessan 1990). Au total 18 provenances de l'aire naturelle sont concernées : 2 de Ceram et d'Irian Jaya (Indonésie), 2 du Sud de Papouasie Nouvelle Guinée, 14 provenances s'échelonnant le long de la côte Est du Queensland entre 12°44' et 18°26' de latitude Sud en Australie.

Le tableau 5 donne à titre d'exemple les caractéristiques à trois ans d'un essai mis en place dans le Sud Est de la Côte d'Ivoire.

Tableau 5: Essai de provenances *Acacia mangium* Anguédédou (Côte d'Ivoire). Données à 3 ans, d'après (Dupuy et N'Guessan 1990)

Provenance	Circonférence moyenne (cm)	% vivants	% tiges multiples
San Pedro (Côte d'Ivoire)	39.3	96	15
Oriomo River (PNG)	39.2	87	25
Claudie River (QLD)	41.2	83	11
Broken Pole Creek (QLD)	38.6	77	24
Ellerbeck Road, Cardwell (QLD)	39.3	66	23
Walsh's Pyramid (QLD)	35.3	86	16
Mossman (QLD)	38.6	72	8
Piru, Ceram (Indonésie)	33.4	57	44
Sidei, Irian Jaya (Indonésie)	26.3	59	31

QLD : Queensland (Australie) ; PNG: Papouasie Nouvelle Guinée

Les principaux résultats des essais mis en place au Cameroun, au Congo et en Côte d'Ivoire sont les suivants :

. La variabilité interprovenance est très importante, que ce soit pour la croissance ou pour la forme. A 2 ans au Cameroun, les hauteurs moyennes varient de 6,4 à 8,3 m suivant les provenances. En Côte d'Ivoire, la productivité à 3 ans varie de 7 à 30 m³/ha/an selon la provenance.

. Les provenances du Sud de Papouasie Nouvelle Guinée (West of Morehead et Oriomo) et la provenance australienne de Claudie River sont toujours classées en tête, alors que les provenances indonésiennes (Piru et Sidei) sont classées en queue.

Ces résultats sont conformes à ceux obtenus sur l'ensemble des essais internationaux mis en place avec les mêmes provenances. Ils ont suscité dés 1985 de nouvelles prospections dans les régions de provenances les plus intéressantes, le Sud de la Papouasie Nouvelle Guinée et l'extrême Nord du Queensland (Australie) avec la participation du Centre Technique Forestier Tropical (Souvannavong 1986). Les graines récoltées ont été utilisées pour la mise en place en Côte d'Ivoire de vergers à graines de familles de 2 des meilleures provenances jusqu'à présent identifiées (Claudie River et Oriomo). Ces parcelles seront les premières sources locales de semences sélectionnées. Elles constituent également un élargissement important de la base génétique disponible pour les programmes de sélection et d'amélioration.

SYMBIOSE *ACACIA MANGIUM* - *RHIZOBIUM*

La croissance rapide d'*Acacia mangium* et sa capacité à coloniser et à régénérer des milieux dégradés sont liées à son aptitude à fixer l'azote atmosphérique grâce à son association symbiotique avec les rhizobiums, bactéries du sol. L'amélioration de cette symbiose induira des gains importants en productivité et renforcera l'efficacité de l'*Acacia mangium* utilisé comme espèce restauratrice de la fertilité des sols, dans les jachères des cultures traditionnelles ou en cultures agricoles intensives (Pommier et al. 1986). Des travaux sont réalisés dans ce but au laboratoire de Biotechnologie des Systèmes Symbiotiques Forestiers Tropicaux (BSSFT-CTFT) situé à Nogent-sur-Marne (France), en liaison avec des instituts de recherche forestière de Côte d'Ivoire et du Bénin. Ces travaux concernent à la fois la sélection des rhizobiums et la sélection - multiplication de la plante hôte, en vue de l'obtention des couples arbre-rhizobium les plus performants.

Sélection des *Rhizobium*

Isolement, caractérisation et sélection des souches de rhizobium

Des nodules racinaires d'*Acacia mangium* ont été collectés dans diverses régions du globe, en Australie dans l'aire d'origine de l'espèce et dans des zones d'introduction en Côte d'Ivoire, au Sénégal (Casamance) et en Guyane. Cette récolte de nodules a permis de constituer une collection d'une centaine de souches après isolement au laboratoire (BSSFT-CTFT).

La caractérisation de ces différentes souches d'*Acacia mangium* en fonction de leur type de croissance *in vitro* et de leur aptitude à noduler d'autres espèces (spectre d'hôtes) a montré leur appartenance au groupe des *Bradyrhizobium sp.* (rhizobium à croissance lente du groupe Cowpea) sans exception.

L'évaluation de l'effectivité d'un grand nombre de ces souches (aptitude à fixer l'azote atmosphérique en symbiose) a été réalisée au laboratoire par dosage de l'azote total des parties aériennes et par la méthode de réduction de l'acétylène. Cette étude a également inclus des souches de *Rhizobium sp.* (rhizobium à croissance rapide) de diverses origines. Elle a montré que seules les souches de *Bradyrhizobium spp.* formaient des nodules fixateurs d'azote effectifs et avaient un effet positif sur la croissance des plants. Il a également été montré que l'effectivité des souches de *Bradyrhizobium spp.* testées était très variable et il a donc été possible de sélectionner des souches très efficientes vis à vis de l'*Acacia mangium*, parmi les souches australiennes en particulier. En comparaison, les mêmes souches présentaient des effectivités égales chez *Acacia auriculiformis*. Il est donc intéressant de recourir à une inoculation de souches de *Bradyrhizobium spp.* sélectionnées lorsque les souches locales sont peu ou pas effectives lors de l'introduction de l'*A. mangium* en plantation. (Galiana et al. 1989)

Essais d'inoculation de rhizobium au champ

Plusieurs souches de *Bradyrhizobium spp.*, testées et sélectionnées au laboratoire (BSSFT/CTFT), ont été envoyées dans différents pays (Côte d'Ivoire, Bénin) sous la forme d'inoculums matriciels. Les essais d'inoculation de l'*Acacia mangium*, ont pour but de tester l'efficience des souches en plantation sur différents types de sol.

Au Bénin sept souches de *Bradyrhizobium spp.* d'effectivités variables ont été testées (Messant 1989). Après 3 mois de croissance en pépinière au sein d'un dispositif expérimental en blocs complets, une partie des plants a été prélevée afin de déterminer le nombre et le poids sec de nodules, la hauteur et le poids sec des parties aériennes. Le classement des souches en fonction de leur effectivité correspondait à celui établi au laboratoire pour des plants cultivés sur milieu sans azote (*in vitro* et en serre) ; les deux souches australiennes utilisées Aust 13c et Aust 11c étant les plus efficientes en produisant des poids secs de parties aériennes respecivement 70 % et 125 % supérieurs à ceux de plants non inoculés.

Quatre des sept souches de *Bradyrhizobium sp.* utilisées dans l'essai qui précède ont été testées au CTFT Côte d'Ivoire (Mallet et Gnahoua 1989). Après 2 mois de pépinière, la croissance des plants, corrélée avec la nodulation, variait significativement selon les souches. La hauteur des plants inoculés dépasse celle des plants témoins non inoculés de 70 % à 110 % suivant les souches.

Six mois après la transplantation des plants au champ, les différences entre les souches tendaient à s'amenuiser, bien que toujours significatives. Les plants inoculés avec les deux meilleures souches conservaient des hauteurs 20 % supérieures à celle de plants non inoculés (215 cm contre 180 cm à 6 mois). L'effet de la provenance d'*Acacia mangium* sur la nodulation et la croissance des plants a également été analysé lors de cet essai. Parmi les quatre provenances d'*A. mangium* testées, la provenance Piru Ceram a donné les meilleurs résultats, quelle que soit la souche de rhizobium utilisée. L'interaction des facteurs "souches" et "provenances" avait aussi un effet significatif sur la variation de ces paramètres.

Sélection et Multiplication de la Plante Hôte

L'autre approche liée à l'étude de la plante hôte concerne l'exploitation de la variabilité génétique du matériel végétal. Cette étude doit aboutir à la sélection de clones sur l'aptitude à fixer l'azote. L'obtention d'un grand nombre d'individus génétiquement identiques pour la mise en place de tests clonaux précoces en laboratoire et en serre, nécessite la mise au point d'une méthode fiable de micropropagation.

Multiplication végétative *in vitro*

L'utilisation des techniques de culture de tissus est particulièrement adaptée dans le cas des arbres forestiers pour l'obtention d'un matériel végétal homogène et permet la multiplication rapide et en grand nombre de génotypes sélectionnés (Sommer and Caldas 1981, Bonga and Durzan 1982). Peu d'*Acacia sp.* ont été utilisés en culture de tissus. Cependant, la micropropagation de plants par hyper-ramification des bourgeons axillaires a été réalisée avec succès chez quelques espèces comme *Acacia albida* (Duhoux et Davies 1985) et quelques essais préliminaires ont même été entrepris chez *A. mangium* (Crawford and Hartney 1987). Contrairement à d'autres méthodes de micropropagation telles que l'embryogenèse somatique ou la régénération de bourgeons adventifs à partir de cultures de cals, la micropropagation par hyper-ramification assure une reproduction conforme des plants et correspond à la méthode la plus adéquate pour la multiplication de clones sélectionnés dans le cadre de l'étude.

La mise en point de cette technique a été réalisée au BSSFT à partir de jeunes semis de 15 jours d'*Acacia mangium* dépourvus de leurs racines et placés sur plusieurs milieux de multiplication. Le milieu optimal a permis la formation d'une vingtaine de rameaux axillaires à partir d'un explant initial après 6 semaines de culture. Des rameaux obtenus après deux subcultures successives sur des milieux de multiplication ont été placés sur des milieux d'enracinement où deux types d'auxines en concentrations variables ont été testées. Un taux d'enracinement de 30 % a été obtenu sur le milieu le plus favorable. Cependant des rameaux axillaires multipliés pendant deux subcultures dans les mêmes conditions que précédemment mais issus de bourgeons axillaires prélevés sur des plants âgés de 7 mois ont pu être enracinés avec un taux de réussite de 70 % (Galiana et Tibok 1988).

Sélection de la plante hôte

Sélection précoce : L'étude de l'effectivité des souches de *Bradyrhizobium sp.* à partir de plants cultivés en serre avait déjà révélé une extrême variabilité dans l'aptitude de la plante hôte à fixer l'azote. Nous avons étudié un procédé de sélection précoce en fonction de la potentialité fixatrice d'azote. 600 plants issus de graines de quatre provenances (150 plants par provenance) ont été cultivés pendant 7 mois sur milieu

sans azote minéral après avoir été inoculés avec la souche de *Bradyrhizobium sp.* la plus effective sélectionnée auparavant. Dix plants ont été sélectionnés : quatre de ces clones nodulant peu et fixant peu l'azote, quatre autres présentant au contraire une nodulation et une aptitude à fixer l'azote exceptionnelles et deux clones ayant des caractéristiques intermédiaires. Ces clones multipliés et inoculés *in vitro* sont actuellement en cours de sevrage (Galiana communication personnelle). Certains d'entre eux vont être mis en place au champ en Côte d'Ivoire au sein de tests clonaux afin de déterminer leurs aptitudes à fixer l'azote *in situ*.

Sélection phénotypique : 40 arbres âgés de 3 à 7 ans ont été sélectionnés sur des critères sylvicoles en Côte d'Ivoire. Ces clones, actuellement en cours de multiplication, seront mis en place en tests avec d'autres arbres témoins.

La mesure de la quantité d'azote moléculaire fixé par les plants pendant leurs premières années sera effectuée par la méthode isotopique de l'abondance naturelle. On pourra ainsi comparer les résultats des deux types de sélection et quantifier avec précision l'input d'azote dû à la fixation symbiotique de l'azote.

ASPECTS PHYTOSANITAIRES

L'*Acacia mangium* est l'objet d'attaques par des champignons et des insectes divers qui n'ont occasionné jusqu'à présent ni une très forte mortalité, ni de pertes de croissance appréciables. Dans son aire d'origine aucun dégât important n'a été signalé. Par contre là où il a été introduit on a dénombré des attaques parfois graves mais toujours localisées à certaines stations ou occasionnelles.

En ce qui concerne les champignons, il faut citer l'Armillaire agent de pourridié qui au Cameroun a provoqué une mortalité de 47 % dans une plantation âgée de 3 ans, le Rigidoporus lignosus autre agent de pourridié qui est à l'origine d'assez nombreux chablis en Côte d'Ivoire (Brunck CTFT, communication personnelle), le Corticium salmonicolor agent de la maladie rose qui au Sabah est occasionnellement à l'origine d'un dépérissement des houppiers (Nas 1983), un Oidium agent d'un mildiou des jeunes plants à Hawaï (Nas 1983) et un agent non déterminé d'une pourriture fibreuse du coeur des jeunes arbres qui est à l'origine d'une certaine mortalité (12 % à l'âge de 44 mois) au Sabah (Nas 1983).

Parmi les insectes, outre certaines cochenilles et aleurodes, ont été répertoriées :

- des attaques de chenilles défoliatrices diverses, notamment celles d'Eurema hecabe, une Pieride qui bien que présente en Afrique de l'Ouest et de l'Est, n'a été signalée comme provoquant des dégâts qu'en Malaisie et aux Philippines (Chey Vun Khen 1987),
- des défeuillaisons dues à des charançons, Hypomeces squamosus, et à des grillons, Nisitra vittata, au Sabah (Toyohiko Mori 1986 ; Chey Vun Khen 1987),

- des attaques des racines par des termites, notamment Coptotermes curvignathus (Toyohiko Mori 1986),

- des attaques du tronc, qui, à l'origine de défauts internes, déprécient fortement le bois. Ces dernières, parfois sévères et toujours très localisées, sont dues à des fourmis charpentières du genre Camponotus (au Sabah) qui occasionnent des pertes pouvant atteindre 32 % (Nas 1983), à des Platypes qui sont à l'origine de piqures noires internes, au Sabah notamment, là où les conditions sont marginales et lorsque les plants souffrent (Toyohiko Mori 1986) et à des Coleoptères Cerambycides qui mulotent le bois et provoquent une gommose du tronc. Il s'agit de Xystrocera globosa au Sabah (Ken Ichi Abe 1983), de Pachystola mamillata en Côte d'Ivoire les taux d'attaque atteignant 80 % à l'âge de 3 ans dans certaines stations toutes les provenances mises en place étant susceptibles (Mallet et Bangre 1988), et d'une espèce encore indéterminée au Cameroun avec un taux d'attaque d'environ 20 % à 2 ans, aucune différence n'étant observée entre les 16 provenances mises en place (Brunck CTFT,communication personnelle).

Enfin, il faut signaler des attaques de Myriapodes, Peridontopyge sp. une iule qui est à l'origine de dégâts importants dans les germoirs de certaines pépinières en Afrique, au Cameroun notamment (Brunck 1984) et une certaine mortalité due aux rats et aux fourmis manioc du genre Atta au Costa Rica (Jimenez et Picado 1987).

CONCLUSION

Introduit en zones tropicales humides de plusieurs pays d'Afrique occidentale et centrale, l'*Acacia mangium* a montré des qualités de croissance et de rusticité qui devraient en faire une des principales espèces de plantation pour la production de bois combustible en zone périurbaine, en utilisant et en régénérant des jachères agricoles appauvries. Une de ses principales qualités est de pouvoir rapidement contrôler le recrû sans entretiens importants, en comparaison avec d'autres espèces à croissance rapide comme les eucalyptus par exemple. *Acacia mangium* peut contribuer à une mise en valeur plus efficace des terroirs tout en satisfaisant un besoin important des populations.

Les recherches intégrées menées dans des domaines complémentaires (sylviculture, sélection et symbioses) ont, en relativement peu de temps, produit des résultats applicables au développement quant à la conduite, la gestion des plantations et le matériel végétal à utiliser. Les travaux concernant l'amélioration de l'efficacité de la symbiose avec les rhizobiums ont donné des résultats très intéressants au laboratoire et en serre. Les essais de terrain récemment mis en place sont prometteurs et devraient aboutir d'ici peu à des applications plus grande échelle dans ce domaine également.

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RADIATION BALANCE OF THE AMAZON FOREST

Y. Viswanadham, R. C. dos Santos, R. G. B. André[1] , A. O. Manzi, V. P. Silva Filho and L. D. A. Sá

Researchers of the Laboratory of Meteorological and Oceanic Research

Instituto de Pesquisas Espaciais - INPE
Secretaria Especial de Ciência e Tecnologia da Presidência da República,
São José dos Campos, SP, Brazil

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SUMMARY

The results from two micrometeorological experiments of undisturbed tropical rainforest at a site (2° 57'S; 59° 57'W) in the Ducke Reserve Forest (DRF) of the Amazon Basin, Amazonas, Brazil are described. Diurnal variation of radiation components is presented. Net longwave radiation was deduced from radiation balance equation. The daily mean albedo varied from 0.08 to 0.18. The derived albedo compared well with those reported by others. The mean value of net longwave radiation for 16 days data sets is about -32 ± 25 W m^{-2}. The values of heating coefficient are found to be in the range -0.303 (May 4, 1987) to 1.320 (April 11, 1985) whereas the values of longwave exchange coefficient are obtained to be in the range -0.569 (April 11, 1985) to 0.435 (May 4, 1987). Predicted regression equations for net radiation from shortwave radiation are presented for the two experimental periods.

Keywords: Amazon Forest, Radiation balance

INTRODUCTION

It has long been recognized that the atmospheric and soil-vegetation systems are dynamically coupled through the physical processes which bring about the transport of thermal energy and water mass across the land surface. This phenomenon explains,

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1 Affiliation from Universidade Estadual Paulista, UNESP, Jaboticabal, SP, Brazil.

to some extent, the importance of current knowledge regarding the micrometeorology of forests. Detailed information regarding the radiation environment above and within forests is, therefore, of great value if we are to understand and accurately model mass and energy exchanges between the forest canopy and the atmosphere. In agricultural and forest meteorology the importance of the net radiation measurements has increased recognition to study regional energetics and resulting physical processes.

In view of this, a brief information of the radiation components above the Amazon forest was reported from two periods experimental data sets: 15th March to 15th May, 1985 and 1st April to 15th May, 1987.

BASIC RELATIONSHIPS

The following were chosen to represent terms in surface radiation balance

$K\downarrow$ = incoming global shortwave radiation ($W\ m^{-2}$)
$K\uparrow$ = reflected shortwave radiation ($W\ m^{-2}$)
Q^* = net radiation for all wavelengths ($W\ m^{-2}$)
$L\downarrow$ = downward longwave radiation from the atmosphere (Wm^{-2})
$L\uparrow$ = upward longwave radiation from the surface (Wm^{-2})
$L^* = L\downarrow - L\uparrow$ = net incoming longwave radiation (Wm^{-2})
α = reflection coefficient for shortwave radiation (i.e., albedo).

From these definitions the net radiation (Q^*) over any surface is defined as (Monteith and Szeicz, 1961; Idso et al., 1969; Gay, 1971; Andre and Viswanadham, 1983)

$$Q^* = (1 - \alpha)\ K\downarrow + L^* \qquad (1)$$

Similarly, the net radiation may also be empirically described by the regression equation

$$Q^* = a\ (1 - \alpha)\ K\downarrow + b \qquad (2)$$

where a and b ($W\ m^{-2}$) are constants determined by the regression.

Eliminating $(1 - \alpha)\ K\downarrow$ from Equations (1) and (2), we have (Monteith and Szeicz, 1961)

$$\beta = -\ (dL^* / dQ^*) = (1 - a)/a \qquad (3)$$

and

$$Q^* = (1 - \alpha)/(1 + \beta) \quad K\downarrow + L^* \qquad (4)$$

where L^* is Q^* when $K\downarrow = 0$ and β is the new parameter, indicative of the degree of surface heating induced by unit increase in net radiation. However, Gay (1969) took a different approach. He eliminated Q^* from the same Equations (1) and (2) and obtained the following relations

$$\lambda = dL^* / d \ [(1 - \alpha) \ K\downarrow] = (a - 1) \qquad (5)$$

and

$$Q^* = (1 + \lambda) \ (1 - \alpha) \ K\downarrow + L^* \qquad (6)$$

Thus, Equation (6) has equivalent with (4). The parameter β may be regarded as a "heating coefficient" and considered as a descriptive property of the surface. On the other hand, the parameter λ is the "longwave exchange coefficient" and may be considered as an environmental property. Both parameters λ and β must either fail or succeed together, as they are directly related to each other (see Equations (3) and (5)). Based on these relations and in an attempt to provide useful informations about the radiation balance, and the parameters β and λ, we have analysed the radiation data sets of the Amazonian micrometeorological experiments.

EXPERIMENTAL SITE AND MEASUREMENTS

The place selected for the experiment is in tropical evergreen forests of the Amazonas basin, Brazil. The measurements were made from a 45m scaffolding tower at a site (2^o57'S; 59^o57'W), situated in the Ducke Reserve Forest (DRF), 26 km from Torquato Tapajós Highway, Manaus, Amazonas. The altitude of the DRF site is 84m above the mean sea level. The DRF belongs to the Instituto Nacional de Pesquisas da Amazonia (INPA), Manaus, Amazonas, Brazil.

The topography of the basin is gently undulating with valleys several tens of meters deep occurring at about 300m intervals. About 75% of the basin is covered with natural forest. The topography of the canopy top is modulated by the differential growth of the vegetation. The tower is sited near the top of a broader than average ridge. The eddy correlation and profile measurements described in this paper assume that the fluxes are one-dimensional and an adequate fetch is required for this assumption. A common intuitive rule by micrometeorologists is that a height/fetch ratio of 1/100 to 1/500 (Bradley, 1968) is needed for about 90 per cent shear

stress adjustment to the underlying surface. The tower has fetches of undisturbed forest extending more than two kilometers in most directions.

All radiation instruments were mounted at a height of 45m at the top of an aluminium scaffolding tower. One upward-facing Kipp solarimeter, two downward-facing Kipp solarimeters and two Funk-type net radiometers were used to provide the measurements of incoming solar radiation K↓, reflected solar radition K↑ and net radiation Q*, respectively. The sensitivity of these instruments is 0.85 mV/mW cm^{-2}. They were mounted perfectly level at the end of 3.5m booms oriented approximately 30° west and 30° east of north. With this orientation there was no possibility of tower shade interfering with the measurements. The mean value of two measurements was considered in the case of net and reflected radiation parameters. The measurements produced by these pairs of instruments agreed with systematic errors of 3% or less: their respective mean values were used in the analysis. All the radiometers used in this experiment have been used and recalibrated over ten years with a total change in calibration of about one per cent over this time. The data were recorded by an analog-digital interface linking system with a microcomputer (Commodore 64). The processed 20 minute data sets from the micro-computer were saved on a disk and a paper print out. The digital noise in the measurements was reduced to around 1.5 W m^{-2}.

RESULTS

Data were selected from the two wet season period expeditions of the Amazon Micrometeorological Project. Unfortunately the first period (15th March to 15th May, 1985) was very dry (no rain) and the second period (1st April to 15th May, 1987) was very wet (almost on all days we had rain). The radiation balance components (Q*,K↓ and K↑) were recorded every twenty minutes. Three consecutive 20 min interval net radiation values were used to obtain one hour means. Data reduction and primary analysis were performed in the field. Only daytime results for four selected days are given in Figure 1. Figures 1a and 1d were presented for quasi-clear days with cloudiness less than 4 octas whereas Figures 1b and 1c were given for cloudy days. In Table 1, the least square linear regression analysis results (Equation (2)) were presented.

Figures 1a - 1d illustrate the relative magnitudes of the radiation components on four sunny days at DRF site. The daily incoming shortwave radiation for 15th April, 1985 and 8th May, 1987 was 19.36 and 19.07 MJ m^{-2} day^{-1}, respectively. André and Viswanadham (1983) have also observed a daily K↓ value of the

order of magnitude 20.5-29.5 MJ m^{-2} day^{-1} above a growing soybean crop at a tropical agricultural experimental station, Jaboticabal (22° 15'S; 48° 18'W), São Paulo, Brazil. The component K↓ is more peaked than other components of the radiation balance. Erratic behaviour of the components K↓ and Q* from 1000 to 1500h of local standard time probably arose due to the amount of convective cumulus clouds being present. The diurnal variation of L* was calculated by differences in results from Equation (1) and, therefore, show irregularities. During these observational days, we observed high temperatures over the forest surface. Also, from 0900 to 1500h (Figure 1) the heat loss by longwave exchange was large in comparison with the early morning and evening hours.

The importance of the reflection coefficient (α) in determining the radiation balance of natural surfaces has been generally recognized. In Figure 1 the diurnal variation of the forest albedo is also presented. During these four days, the albedo at a given local time was approximately constant except in the early morning and evening hours. This is due to the large amount of energy received when the sun is high. It is also caused by the trapping of radiation beneath the dense forest canopy. The effect would be reduced at large zenith angles (morning and evening hours) since the direct solar radiation would not penetrate to such an extent. In summary, the mean albedo values for the selected days vary between 0.08 to 0.18 (Table 1). These results are comparable to albedo values reported for other forests (see Moore, 1976).

Table 1 shows that the correlation coefficients for regression analysis were high and they varied from 0.83 to 0.99. The F values indicate that the regression constants (a and b) obtained are highly significant above a 99% significance level. Values of β and λ were calculated from the regression slopes (a) according to Equations (3) and (5), respectively and they are also presented in the same table. Generally, r values revealed the statistical significance of β and λ . Thus, it must be concluded that, in general, the statistical basis for the development of β and λ, is quite good. Sometimes it is apparent that β and λ are not significant statistically, the only remaining consideration must be their descriptive value. This consideration, however, should really only deal with the regression slope "a", relating Q* to $(1-\alpha)$ K↓ ; for both β and λ are directly expressible in terms of this basic parameter (see Equations (3) and (5)). Thus, it may consider below the significance of having $a<1$, $=1$, and >1, in light of the corresponding properties assigned by Gay (1969) to values of λ <0, $=0$, and >0. Table 1 shows the first and third cases.

In the first case ($a < 1$; $\lambda < 0$) the more descriptive equation relating Q^* and $(1 - \alpha)\,K\downarrow$ shows that $(1 - \alpha)\,K\downarrow$ is increasing faster than Q^* in the morning and decreasing faster in the afternoon. Thus, $L\uparrow$ must be successively increasing and then decreasing faster than $L\downarrow$, to slightly change the diurnal variation of Q^* compared to that of $(1-\alpha)\,K\downarrow$. This effect may be interpreted such that the canopy surface temperature successively rises above and then falls to the air temperature, thus allowing a midday peak in the partitioning of absorbed solar radiation into storage and convection. Generally, it is well known that there is a convective activity from morning to evening over the Amazon forest. These results clearly give evidence for this situation ($\lambda < 0$). The third case ($a>1$; $\lambda > 0$) was only observed during the April to May, 1987 period. Because of an increased interception of precipitation, more evaporation (Shuttleworth, 1988) should occur for a taller green vegetation canopy surface for a given energy input. This, in turn, should create a cooler radiative canopy surface temperature (Viswanadham and André, 1983) and, thus, a greater net radiation above the forest surface, whereby a greater slope of Q^* on $(1-\alpha)\,K\downarrow$ would result.

The daily cycles for 4 days (Figure 2) show that for a given incoming net shortwave radiation, the net radiation is less in the afternoon than in the morning, possibly due to higher surface temperatures in the afternoon. The separation of the morning and afternoon data gives a measure of the asymmetry of the diurnal net radiation patterns.

It is hazardous to apply the results presented here to other areas with different meteorogical conditions, even if surface characteristics are very similar. If the net longwave radiation can be estimated then the data indicate that net radiation Q^* may be predicted from the incoming shortwave radiation $K\downarrow$. The following equations for the Amazon forest

$$Q^* = 0.709\,K\downarrow - (15.81 \pm 8.93)$$ (April - May, 1985 very dry conditions prevailed)

and

$$Q^* = 1.006\,K\downarrow - (48.01 \pm 24.89)$$ (April - May, 1987 very wet conditions prevailed)

were determined using the regression relationship constants and the mean albedo (Table 1). Limitted space prevents further elaboration of results.

Additional measurements of this type for other natural surfaces would be useful in many types of investigations,

including studies of the atmospheric and surface energy balance, and remote sensing of the environment.

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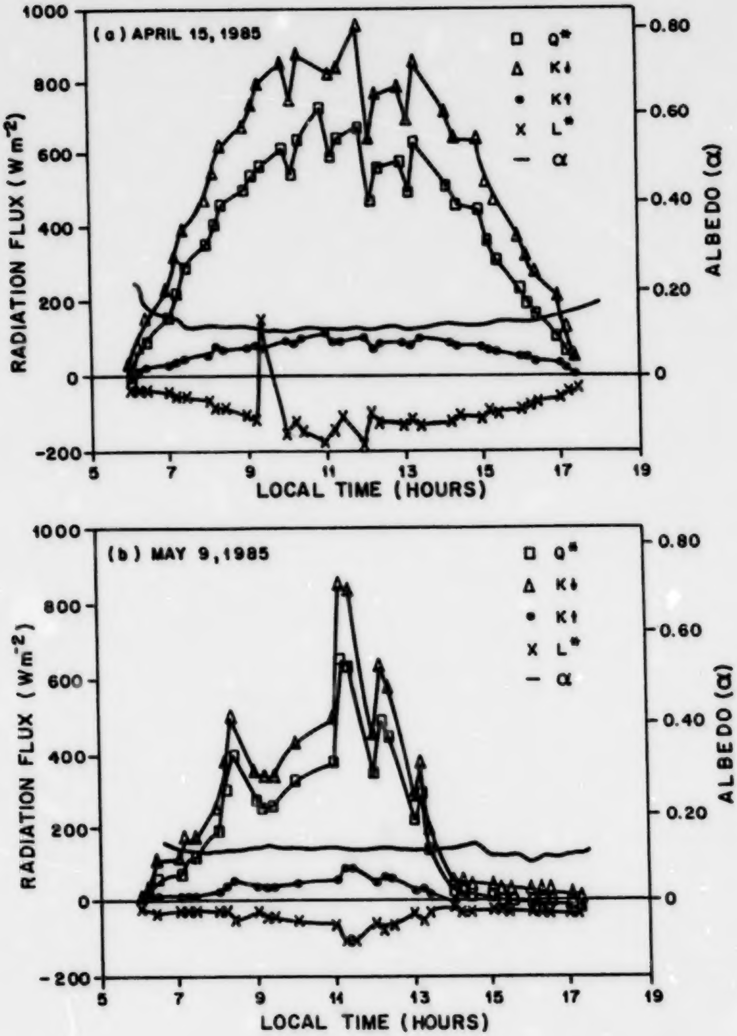


Figure 1: Daily variation of the radiation components over the Amazon forest canopy surface.

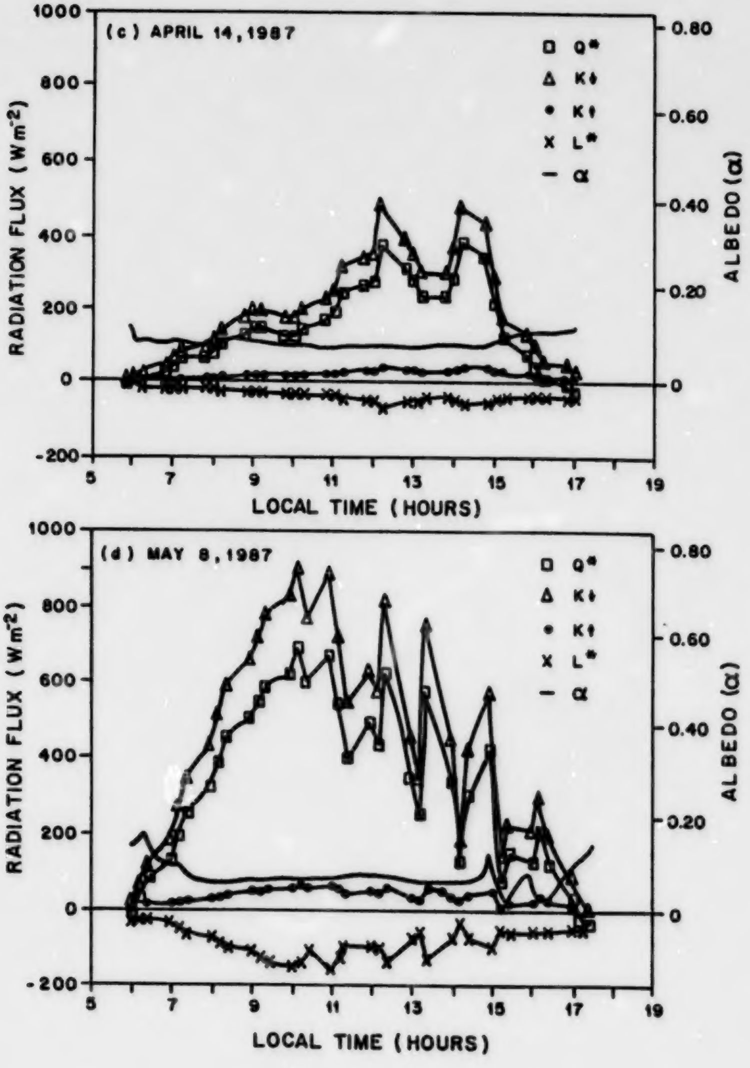


Figure 1: (Continued).

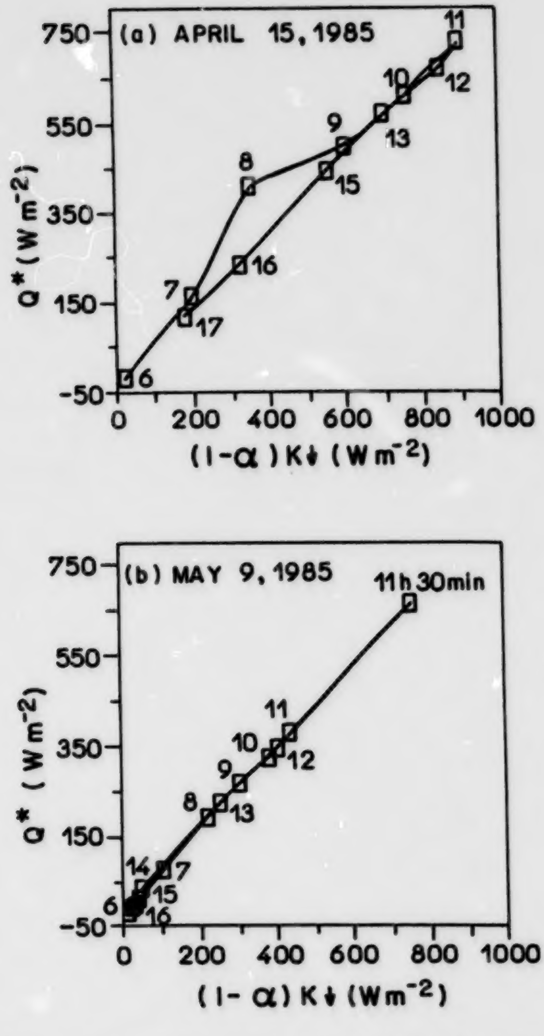
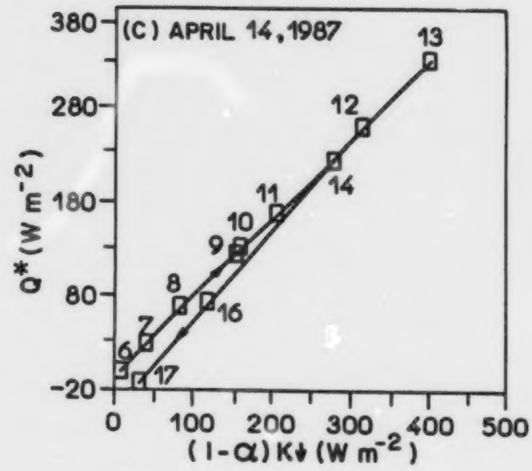


Figure 2: Variation of hourly values of Q* and (1-α)K↓ over the Amazon forest canopy surface.



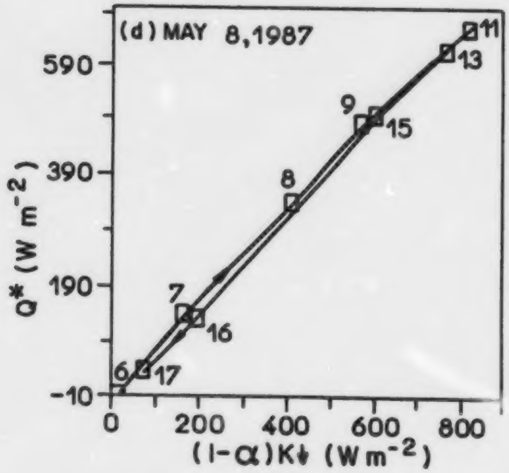


Figure 2: (Continued).

Table 1: Different parameters from the regression analysis of the radiation balance Equation (2)

Date	n	b	a	r	Sy.x	F	β	λ	α	cloud
April 1985										
4	30	-9.42	0.808	0.99	[illegible]	1470	0.238	-0.192	0.15	2/8Cu
10	34	-18.88	0.825	0.99	1[illegible].64	1568	0.212	-0.175	0.12	clear
11	15	-3.28	0.431	0.99	11.67	643	1.320	-0.569	0.13	2/8Cu
16	31	-30.48	0.831	0.92	40.61	160	0.203	-0.169	0.13	3/8Cu 1/8AC
18	30	-12.02	0.867	0.92	30.50	154	0.153	-0.133	0.13	4/8Cu
May 1985										
2	23	-16.92	0.892	0.99	11.40	1029	0.121	-0.108	0.14	3/8Cu 2/8AC
5	33	-27.60	0.939	0.99	16.35	1519	0 065	-0.061	0.13	2/8Cu
10	36	-7.84	0.927	0.99	5.67	1666	0 079	-0.073	0.13	2/8Cu
Mean		-15.81	0.815				0.299	-0.185	0.13	
S.D.		8.93	0.152				0.390	0.152	0.01	
April 1987										
11	36	-34.01	1.007	0.94	67.20	258	-0.007	0.007	0.13	3/8Cu 3/8AC
14	35	-22.09	0.900	0.99	10.17	4455	0.111	-0.100	0.09	2/8Cu 5/8AC
15	20	-33.28	1.289	0.98	45.08	437	-0.224	0.289	0.11	7/8St
20	36	-35.70	1.164	0.91	103.82	163	-0.141	0.164	0.13	5/8Cu
May 1987										
2	36	-58.54	1.064	0.83	114.27	76	-0.060	0.064	0.11	2/8AC 3/8St
4	33	-105.90	1.435	0.90	124.27	132	-0.303	0.435	0.16	3/8Cu 4/8AC
5	36	-58.63	1.321	0.85	144.29	88	-0.243	0.321	0.18	3/8Cu 2/8St
6	30	-35.94	0.961	0.98	25.67	1188	0.041	-0.039	0.08	5/8Cu
Mean		-48.01	1.143				-0.114	0.143	0.12	
S.D.		24.89	0.178				0.130	0.178	0.03	

n is number of observation; a is slope; b is intercept; r is correlation coefficient; Sy.x is standard error of estimate; F is the F-test values; β is heating coefficient; λ is longwave exchange coefficient; α is albedo.

* Observations from 1300h to 1700h were only available.

RESEARCH NEEDS AND METHODS FOR TROPICAL SILVICULTURE WITH SPECIAL REFERENCE TO AFRICA

P J WOOD

SENIOR RESEARCH OFFICER
C/O OXFORD FORESTRY INSTITUTE, ENGLAND

FDC: 23: 945.4 (213)

SUMMARY

Tropical silviculture research in Africa is urgently needed, although there is much information and technology that is at present unused or neglected in solving problems. In order to formulate research programmes in silviculture that really address the problems facing much of tropical Africa it is essential that research topics are derived from field needs. From the wide array of research needs it is then important to examine and prioritise topics from the point of view of national needs. Three areas of research in areas related to tropical silviculture which deserve more attention are the investigation of the silvics of tropical trees, the management of rangelands and the improvement of plantation management. Once a research topic has been selected existing information and research techniques should be examined to assist the planning stage.

1. RESOURCES FOR RESEARCH IN AFRICA

Whilst it is not possible to generalise about tropical Africa as a whole, certain points are common amongst African countries which have a bearing on national abilities to carry out good silvicultural research. Most silvicultural research officers are in the government service, for which resources are always limited, whether of personnel, funds or hardware. Secondly, experience is often lacking, not because there are no experienced research officers, but because there is an inadequate pool of qualified personnel to replace officers who emigrate, go to work for international agencies, or leave posts temporarily to undertake postgraduate studies, attend conferences and the like. There is often frustration at the lack of political or financial support for the policies and programmes that national officers have developed. And the long term nature of much forestry and agroforestry research makes it more difficult to manage, yet training in research often tends to concentrate more on scientific study than on efficient identification and management of research programmes. In the private sector the situation is generally different with rewards for the production of well-focussed results, and realistic allocations of resources for work of high company priority.

1.1 Small is Beautiful ?

The above is, of course, a simplification of the situations facing African research organisations, but a review by Palmer (1989) reports in more detail a number of studies carried out in the 1980s in which many of these problems are reported to be common. For example, much concern was expressed by Directors of forest research organisations over their small size compared with their agricultural counterparts. There was a great deal of concern over the difficulties of making convincing cases to politicians and others of the potential economic and ecological value of forestry research, even when all the technical information was at hand. In a majority of African countries forestry research organisations are understandably small, so that there is no opportunity to build up a "critical mass" of research staff. Moreover, although low salaries in the government services of developing countries do not only affect research officers, small institutes with small cadres of research officers do lack opportunities for promotion.

1.2 IUFRO's SPDC in Africa

IUFRO has focussed on some of these problems through its Special Programme for Developing Countries which is also reporting at this Congress and has devoted much of its efforts since 1983 to the organization of regional workshops for the planning of forestry research by the countries themselves. It is significant that, out of the 5 workshops held up to the end of 1989, 3 were in Africa, and the developments from these have included strengthening of research in Djibouti and Somalia, setting up several seed centres in different countries and considerable development and increased political support for forestry research through CILSS in the Sahel. The meetings held so far on the silvicultural or "growing" side of forestry research were:

Kandy 1984 for tropical South and South East Asia (Shea and Carlson 1984, Burley and Stewart 1986);

Nairobi 1986 for the Sahelian and North Sudanian zones of Africa (Carlson and Shea 1986);

Nairobi 1987 follow-up meeting for the Sahelian and North Sudanian zones (Iyamabo et al., undated but 1988);

Huarez 1987 for tropical and subtropical Latin America (Palmer et al. in preparation);

Lilongwe 1988 for the "miombo" and savanna woodland zone of east-central and southern Africa (Iyamabo et al. in preparation);

1.3 TFAP Initiatives

The Tropical Forestry Action Plan (TFAP) initiative has made the point in many countries that an essential prerequisite to research planning is the formulation of an agreed national forestry policy. If forestry research is to be supported nationally, however, it must not only meet needs perceived at the top policy levels, but must also respond quickly, through empirical research activities, to the immediate needs of users of research results. If it does not, it runs the risk of being replaced, or becoming an "ivory tower", unrelated to field needs. More than one Director of a forest service in Africa has been heard to remark that if the research service does not produce the information he needs, he will seek to set up his own "management" research organisation. It is therefore important to examine what types of research in tropical silviculture can be undertaken, how the subjects for research are selected, and some of the ways in which efficiency can be helped in the research done.

2. TYPES OF RESEARCH

The great demographic and land-use pressures that characterise much of tropical Africa have focussed attention more and more on desertification, deforestation and the social problems of food, fodder and fuelwood shortages. This is not the place to repeat concern over these very important matters. What is of concern, however, is that the urgency of finding solutions has often tended to bypass the capability of silviculturists to research upon solutions. It is still often important to ask : Why is research necessary ?

Table 1, adapted from a policy statement of the International Rice Research Institute, shows the classical approach of agronomists. Inevitably it leads to a top-down approach of the "lab to land" type, which served extremely well those institutes dealing with a narrow range of commodity crops, but is less applicable where a more holistic view of land use is taken, as in agroforestry or in rural development forestry in general. All types of research, however, have as a main objective the improvement of an existing land use situation. This framework is widely used in forestry as well as in agriculture, but may not be so relevant for silvicultural or agroforestry research where large numbers of species and possible management systems exist.

A recent alternative classification for applied forestry research is given by Sutton (1986) who lists three basic categories:

- Problem orientation
- Service orientation
- Innovation.

Problem orientation would include, for example, controlling pests and pathogens, selecting species for use in rural afforestation, identifying indigenous germplasm in natural forests, or controlling soil erosion. The main clients would be silvicultural managers or farmers.

Service orientation would include the refinement and optimization of current practices, such as the spacing of trees in plantations, thinning practices, maximizing recovery of all kinds of forest products or investigating marketing strategies. The clients here would be both field managers and farmers, and also national economic planners.

Table 1.

Dominant research phase	Dominant research mode	Primary research location	Primary research cooperation
BASIC	New understanding	In laboratories of advanced research institutions	Collaboration with advanced research laboratories
STRATEGIC	Technology generation	Mainly at research stations; technical feasibility	Advanced labs with NARS at key research sites representative of major constraints or environments
APPLIED	Technology refinement	At research stations and on-farm, mainly researcher-managed; technical, managerial and economic evaluation	Advanced labs in collaboration with many NARS at national sites; research linkages facilitated through networks
ADAPTIVE	Technology synthesis and evaluation in target environments	On-farm with farmer involvement and broader socio-economic and impact analysis	In many countries and at many sites, with major initiatives taken by NARS; supported by international networks.

[NARS = national agricultural research services; after Burley, 1989]

Innovation covers the development of new technology and presents most risks for the researcher and for the donor, but has the greatest long term potential. However, it can only be done effectively be carried out by researchers of high calibre and long experience, and where most research staff are recent graduates there is no real alternative to waiting for the necessary experience to be built up. Research of any kind which merely repeats what others have done, or is without relevance to national policies is generally a waste of time. The kinds of research included as innovation might be the development of novel land use systems in agroforestry, or genetic engineering, for example. The clients here are all the above, plus a wider range of human populations, international as well as future generations.

This framework makes the clients the basic factor in the classification and seems to be particularly realistic for silvicultural research. The identification of the client is central to the "Diagnosis and Design" approach of ICRAF, for example, (Raintree, 1987), in which it is quite clearly the farmer or rural land user, and ICRAF's research programmes are firmly based on the identified and perceived needs of these groups. The further from the immediate client that the research is, however, the more risky the research becomes. Risk, both to the researcher and to the provider of funds, is greatest in the case of innovation despite the potential benefits of technological break-throughs, and it may be argued that innovation should be given the lowest priority of any of the three classes of research. In silviculture the objective is to improve an existing situation with the conviction that the use of trees is one of the ways of achieving this.

3. METHODS OF PRIORITISING RESEARCH PROPOSALS

3.1 Rural Appraisals

The particular form of rural appraisal developed by ICRAF as "Diagnosis and Design" (D&D) was specifically formulated to provide research topics that addressed problems and supported potential improvements in existing land use systems. It follows a logical series of steps: Pre-appraisal survey - field visits and farm interviews - brainstorming of possible interventions - design of new systems or design of appropriate research programmes (Raintree, 1987). At all levels of this process prioritisation of options is carried out, and there is much scope in the methodology for iterative re-examination of sites and further discussions with farmers as plans progress.

Table 2.

CRITERIA FOR FORESTRY RESEARCH ADAPTED FROM CGIAR GUIDELINES

- The research activity should be of present or potential importance to the contribution of forestry to national or local development
- There should be clear evidence that there is potential for substantial progress or improvement in the activity
- There should be clear evidence that such improvement is now limited by deficiencies in presently available scientific technology and lack of the required information
- There should be a good prospect that new scientific information and technology on the subject can be developed and could be brought into use.

"D&D" thus represents a typical field-level diagnosis, particularly oriented to site-specific trials in agroforestry, and to well-balanced on-farm research programmes. There are dangers, of course, in relying too much on learning technology from farmers, who are necessarily less aware of potential options than are outside specialists. Rural appraisal must learn about farmers' problems, survey and interpret the land use situation and discuss possible interventions.

At the other end of the scale is the top down approach in which problems are defined from scientists' experience of land use systems. If this is done in close contact with managers the end result may be very similar, but if done solely by researchers - as is the tendency in "lab to land" approaches- the resulting programmes may well bear more relationship to scientists' aspirations than to national or local problems and potentials. In such circumstances rigorous examination of the proposals against agreed guidelines is needed. The CGIAR institutes have listed a number of criteria which are shown adapted to forestry subjects in Table 2.

3.2 Is Research at all necessary ?

These and other thoughts have been developed into a simple format for examining research priorities, given in Table 3 and which has been used in East Africa and elsewhere (Wood, 1989). The first question to be examined is whether lack of research is really a major constraint on implementing a desired improvement in the land use system. Or is the constraint lack of funding, training or of political will ? This must be assessed very carefully. Second, because of the overriding importance of political support for research funding, the proposal must be measured against national policy statements. If the proposal passes both these criteria it is then considered from sociological, extension, environmental and ecological standpoints and ranked according to a simple scoring system.

4. PRIORITIES FOR SILVICULTURAL RESEARCH

4.1 Bellagio II findings

The report of the International Task Force on Forestry Research-Bellagio II - (Anon, 1988) is a most valuable starting point to take an overview of silvicultural research priorities. It starts with the four areas of opportunity addressed by the Tropical Forestry Action Plan:

- The contribution of forests and trees to sustainable land use and food security
- The contribution of forests and trees to energy security
- The expansion of sustainable forest industry development
- The conservation and management of tropical forest ecosystems.

From these the report identifies five fields for priority attention:

** agroforestry and watershed management
** natural forest ecology and management
** tree breeding, tree improvement and establishment
** utilisation and marketing
** policy and socio-economic issues.

Tropical silviculture clearly has a role to play in many of the subject areas. There are, however, three subjects which would seem to deserve more attention, and it may be useful to draw attention to some of these.

4.2 Tropical Silviculture Priorities

One important area is that of increasing knowledge of the silvics of trees and shrubs. Another is the problem of rangeland management and a third is the refinement of management in plantations. The first may require innovative research but is also service oriented, whilst the second is largely innovation at the present time. A third area is well understood in some outstanding (commercial) plantation projects, such as the *Eucalyptus* schemes in Congo, Brazzaville or Aracruz, Brazil and is fundamentally service oriented research.

4.2.1. Investigating the silvics of trees and shrubs

The concept of the "multipurpose tree and shrub" was developed mainly to broaden attention away from a narrow range of fast growing plantation species such as the tropical pines and Eucalypts. In the rural development and agroforestry situations, however, many more species are used. To undertake genetic improvement programmes on a large range of species (over 2,000 are currently on ICRAF's Multipurpose Tree Database) is neither possible nor desirable, but the fundamental investigation and recording of autecology and synecology, of the basic biology, breeding system, phenology and uses of a

Table 3.

A SUGGESTED FRAMEWORK FOR SELECTING AND PRIORITISING TROPICAL SILVICULTURE RESEARCH TOPICS

All research should be aimed at improving an existing situation - in silviculture these are land use systems which are examined in relation to national policies. Two questions must therefore be asked before the topics can be examined further:

1. IS IMPROVEMENT CURRENTLY LIMITED BY LACK OF RESEARCH ? IF YES, CONTINUE. IF NOT, THE RESEARCH TOPIC SHOULD BE REJECTED.

2. IS THE RESEARCH OF POTENTIAL IMPORTANCE IN LOCAL OR NATIONAL DEVELOPMENT ? IF YES, CONTINUE. IF NOT REJECT THE RESEARCH IN FAVOUR OF WORK THAT ADDRESSES REAL PRIORITIES.

If the proposal passes the above, rate it for the following criteria, scoring 3=HIGH, 2=MODERATE, 3=LOW, 0=ZERO: -

	SCORE (0-3)
1. IS THERE GOOD EVIDENCE THAT SUBSTANTIAL IMPROVEMENT CAN BE OBTAINED BY UNDERTAKING THIS RESEARCH ?	
2. WHAT IS THE LIKELIHOOD OF ANY NEW TECHNOLOGY BEING ADOPTED BY FARMERS OR OTHER LAND USERS ?	
3. WHAT NUMBER OF PEOPLE ARE LIKELY TO BENEFITED BY ANY NEW TECHNOLOGY ?	
4. WHAT AREA OF LAND IS LIKELY TO BE IMPROVED BY ANY NEW TECHNOLOGY ?	
5. WHAT ARE THE POTENTIAL SOCIAL BENEFITS FROM ANY NEW TECHNOLOGY ?	
6. WHAT ARE THE POTENTIAL ECONOMIC BENEFITS TO BE OBTAINED FROM ANY NEW TECHNOLOGY ?	
7. WHAT LEVEL OF ENVIRONMENTAL IMPROVEMENT MAY BE EXPECTED FROM ANY NEW TECHNOLOGY ?	
8. WHAT LENGTH OF TIME IS PROBABLE FOR THE RESEARCH ? (<5 YRS; 5-10 YRS; 10-15 YRS; >15 YRS)	

The format is designed to be used as a basis for discussions between researchers, planners and policy-makers. In this form the maximum possible score is 24. It is possible to give different weightings to different questions, but uniform weighting should provide a reasonable basis for ranking alternative research topics.

Derived from Wood, 1989.

large range of species is work that can be undertaken at many different levels and in a piecemeal fashion. The availability of results of such work is vital to the design of new agroforestry practices and rural development forestry, both of plantations and natural forests. The concept of the "ideotype" - a specific phenotype with defined characteristics and performance - is being broadened in forestry to cover groups of phenotypes of different species, a kind of species end-use grouping familiar in timber utilisation. One of the main products from compiling information on silvics is end-use groupings of species for broad categories of silvicultural roles, especially in rural development and agroforestry.

4.2.2. Applying silvicultural principles in rangelands

Very large areas of rangelands exist in Africa and the Indian sub-continent that are not supported by crop-oriented agronomic research. The situation is somewhat different in Latin America where ranching is a major land-use practice and most of such lands are in private ownership. In Africa rangelands are seldom under any kind of forestry or agroforestry management, and the main inputs from livestock specialists are in relation to animal health. Such areas are generally common lands or common property and it is therefore difficult to improve the management without much research into the sociological patterns of current use. The management of such lands for browse -a word little used by foresters - as well as timber, fuel and other tree products, demands a multidisciplinary approach between silviculturists and range specialists with inputs from sociology. Without this kind of approach, in which the demonstration element is as important as that of research, attempts to address the problems of desertification are likely to miss the main target group.

4.2.3 Research for optimising plantation management

There are many areas suitable for industrial forestry plantations in Africa which could be planted without environmental disbenefits and with considerable economic benefits to national economies or are already planted and which are performing much below their potential.

On well-favoured sites in east and central Africa mean annual increment yields of 25 to 40 cubic metres per hectare can be obtained from well-managed plantations. Yet the actual yields from operational plantations are often half this or less. Poor or slipshod management may only reduce efficiency by a few percent at each stage - seed handling, nursery work, planting techniques, timing and intensity of thinning and pruning, timing and technique of harvesting - yet the cumulative effect is a massive loss of potential industrial raw material. The same applies to small scale rural development forestry but is less easy to remedy. The success stories from Congo, Malawi, Zambia, Zimbabwe, for example, indicate the importance of closely focussed research on refining management methods coupled with the discipline to carry out research findings.

Table 4.

RESEARCH NEEDS AND METHODS FOR TROPICAL SILVICULTURE WITH SPECIAL REFERENCE TO AFRICA
MAJOR TROPICAL FORESTRY RESEARCH PROBLEMS - AN APPROACH TO PLANNING

PROBLEM DESCRIPTION	NOTES ON WHAT IS ALREADY KNOWN (WITH REFERENCES)	ASPECTS OF THE SUBJECT TO STUDY	AVAILABLE RESEARCH TECHNIQUES	REMARKS
UTILIZATION OF FUELWOOD FROM FARM WOODLOTS	CALORIFIC VALUES AND DENSITY PROPERTIES FOR MOST COMMON SPECIES (ODNRI, 1978)	STUDIES ON UNKNOWN SPECIES	CALORIFIC TESTS FOR UNKNOWN SPECIES AND TESTS IN DOMESTIC AND RURAL USE FOR ALL SPECIES	TESTS TO BE DONE IN SELECTED RURAL HOUSEHOLDS AND AT RURAL CENTRES
ECONOMICS OF HARVESTING AND SALE OF TREE PRODUCTS FROM SMALL SCALE PRODUCERS	FOR SPECIFIC AREAS SIZE OF HOLDINGS AND QUANTITIES, QUALITIES AND TIMINGS OF PRODUCTION (RESULTS OF FIELD SURVEYS)	1)SURVEY OF MARKETS AND DISTANCES	1)STANDARD FIELD SURVEY METHODS IN RELEVANT CENTRES	
		2)STUDY OF EXISTING SUPPLY AND DEMAND TO ASSESS EFFECTS OF NEW SUPLIES ON PRICES	2)HISTORICAL STUDIES AND ECONOMETRIC ANALYSIS	
		3)SURVEY OF TRANSPORT MEANS AVAILABLE AND TRENDS	3)GOVERNMENT STATISTICS, MAPS AND PLANS OF SUPPLY AREAS, COSTS IN RELATION TO NATIONAL DEVELPMENT PARAMETERS	

This requires a rigorous management system for decision-taking; research should therefore also indicate the economic consequences of not carrying out required work at the specified time. Time is critical in minutes in nurseries, in days at planting, in weeks for weeding and in months for thinning. Yet how often is this translated into management orders ?

5. HOW IS RESEARCH CONDUCTED ?

In order to ensure optimum use of resources research must be planned. The key points as illustrated in Table 4 are:

- A clear definition of the problem.
- Notes on what is already known, with references, professional contacts, places where similar problems have already been solved.
- The aspects of the subject to study, i.e. the probable subjects of individual experiments or field surveys.
- An indication of available research techniques, leading to an assessment of existing research facilities for the work proposed.
- Remarks amplifying the above, but with special notes on whether research is to be on-farm or on-station, any local conditions that need to be examined, etc.

In conclusion. it is strongly contended that much more time should be spent on planning research, especially in tropical silviculture, to avoid duplication of effort, "re-invention of the wheel" and researching upon subjects which are unrelated to national priorities.

LIST OF ACRONYMS

AFRENA: Agroforestry research networks for Africa (ICRAF programme)

CGIAR: Consultative Group on International Agricultural Research, USA

CILSS: Comité permanent Interétats de Lutte contre la Sécheresse dans le Sahel, Burkina Faso

FAO: Food and Agriculture Organization of the United Nations, Italy

IIED: International Institute for Environment and Development, [illegible] and USA

SAREC: Swedish Agency for Research Cooperation with Developing Countries, Sweden

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THE ECONOMICS OF SMALLHOLDER RATTAN CULTIVATION

Ricardo Godoy

Harvard Institute for International Development
Harvard University
One Eliot Street
Cambridge, MA 02138, USA

FDC : 287: 651

SUMMARY

In this paper the author: (a) discusses the uniqueness of rattan among non-timber forest products, (b) examines the financial and the economic profitability of smallholder rattan cultivation, and (c) outlines a strategy for expanding smallholder rattan plantations among non-traditional producers.

Key words: Rattan, irit, non-timber forest products

INTRODUCTION

The humid forests of developing countries are being rapidly depleted from population pressure and misguided sectoral and macroeconomic policies (Repetto and Gillis 1988). Poor people destroy much of the forests in these countries as they try to maintain incomes constant. To lower the pressure put on the forest, scientists and policy makers have urged national governments to encourage the extraction of non-timber forest goods and the creation of buffer zones through enrichment planting of established forest stands.

Although meritorious in the abstract, the creation of buffer zones have not generally improved the income of the rural poor. Technicians have designed buffer zones yet smallholders have not usually adopted newly engineered agroforestry systems because the products grown in these systems lack well-developed markets and, consequently, cannot meet smallholders' income needs. In some cases, new agroforestry systems have not gone beyond the experimental plot. The scientists responsible for the development of new agroforestry systems have paid scant attention to the economic incentives necessary for the successful diffusion of these systems among smallholders.

Raising smallholder income through sustainable agroforestry systems or through the extraction of non-timber forest goods and services faces a number of constraints. First, the mix of trees

and tree products to be exploited by smallholders must face well developed markets. Financial incentives provide smallholders with a strong stimulus to plant and to care for trees (Godoy and Murray 1989). Second, the crops should tolerate neglect. This allows farmers to pursue other economic activities, particularly outside the farm, during market downturns. Third, the products grown in these systems should face a high price elasticity of demand so that increased supplies do not harm producer prices or smallholder incomes.

Unlike other non-timber forest goods, rattan has the potential of enriching the forest in a financially and ecologically viable way. Rattan cultivation can raise smallholder income because rattan enjoys an expanding world market and rising prices. Requiring arboreal support, rattan cultivation does not produce environmental degradation. Preliminary evidence indicates that raw and semi-processed rattan faces a high world price elasticity of demand, suggesting that increased supplies of rattan will not have much adverse effect upon world prices or smallholder incomes.

In the balance of this paper I will argue that international development agencies concerned with the fate of the humid tropics as well as Third World governments, particularly outside Asia, should begin to explore the potential of establishing smallholder plantations of rattan or canes similar to rattan. At present, rattan is one of the few non-timber commodities that can absorb supply increases without harming producer prices or smallholder incomes. The world market conditions are ripe to begin thinking about strategies for establishing smallholder rattan plantations among non-traditional producers both in Asia and outside Asia.

The balance of this paper is divided into two sections. In the next section I discuss the financial and the economic profitability of smallholder rattan cultivation. Policy analysts must prove both the financial profitability to farmers and the economic profitability to the nation of establishing smallholder rattan plantations before donor organizations or Third World governments can endorse this strategy. Economics tends to be an afterthought in much agroforestry research. The next section therefore contains a discussion of some rather dry but important empirical estimates of profitability. The last section contains a discussion of why non-traditional rattan producing countries should begin to explore the possibilities of cultivating canes.

THE PROFITABILITY OF SMALLHOLDER RATTAN CULTIVATION

The Importance of Rattan

To achieve sustainable management of humid tropics, scholars and policy analysts have began to emphasize the need for the judicious extraction of non-timber forest products as an alternative to logging (ITTO 1988; Peters et al 1989; de Beer and McDermott 1989). Though meritorious in the abstract, this alternative is flawed, at least in the short run, because most of these products lack well-developed markets. Rattan differs. Widely used in the village economies of Asia for centuries, rattan also enjoys an expanding and successful international market. As Figure 1 shows, real world prices for rattan have increased sevenfold since the early 1970s.

Among non-timber forest products, rattan ranks highest in value. For example, during 1982-1986 rattan accounted for about 75% of total non-timber forest product exports in Indonesia (Miranda 1987). In a normal year, the exports of raw and semi-processed rattan from Indonesia reach about US$ 100 million, far beyond the value of any other non-timber forest good. Some analysts have argued that the use of export statistics undervalues the importance of non-timber forest commodities because these commodities do not move beyond the village economy (de Beer and McDermott 1989). The use of export statistics does not change the ranking of rattan relative to other non-timber forest products. Since villagers use rattan widely in the local economy (Dransfields 1988; Connelly 1985:42; Siebert and Belsky 1985:531; Peluso 1983; Weinstock 1983), the use of export sales to measure the importance of rattan captures the value of this commodity beyond its contribution to the domestic economy.

Owing to rising real prices over a protracted period, smallholders in Asia have expanded both collection of rattan from the wild and, less commonly, cultivation of rattan in secondary forests and abandoned rubber stands. In areas endowed with ideal growing conditions, smallholders have developed essentially monocrop agroforestry systems with rattan at their core. For instance, in the village of Dadahup, along the lower Barito basin in Central Kalimantan, Indonesia, monocrop rattan gardens account for over 90% of smallholders' cash income (Godoy and Ching Feaw 1989).

The Returns from Plantings Rattan

Godoy and Ching Feaw (1989a) have carried out a detailed cost/benefit analysis of the financial and the economic returns from cultivating rattan in a smallholder setting along the Lower Barito basin in Central Kalimantan. In this section I will summarize and expand on the results of that study.

Although other analysts have measured the private profitability of rattan cultivation (Salim 1982; Shim and Tan 1984; Priasukmana 1986; Noor and Razali 1987), we went beyond a financial analysis to shadow price smallholder rattan cultivation. We evaluated the financial and the economic returns of cultivating rattan irit (*Calamus trachycoleus*) in one hectare of secondary forest and abandoned rubber stands over 25 years using a real discount rate of 10%. Since farmers sell both green and processed canes, we carried out analyses for both of these goods. We express all values in real terms at the farmgate. We used the Net Present Value (NPV) and the Internal Rate of Return (IRR) investment criteria to measure profitability.

To carry out this analysis we estimated a number of parameters. Table 1 contains a summary of the key parameters for quantities, financial and shadow prices, real growth rates, and nursery costs. We derived parameters for financial prices and for quantities by interviewing farmers; because of the brevity of fieldwork, we were not able to obtain a representative, stratified random sample of farmers. Yield data was supplemented with estimates from Malaysian plantations.

Table 1: Parameters for Financial and Economic Analysis

I.	Area (hectare)	1
II.	Species : irit (*Calamus trachycoleus*)	
III.	Growth rates and yields:	
	A. Rate of growth (m/yr)	4
	B. Year of first harvest	7
	C. Net yields of green cane at maturity (mt/ha)	1.47
IV.	Labor	
	A. Land preparation (person-days/ha)	11
	B. Maintenance (person-days/ha/year)	5
	C. Harvesting (kg of green cane/person/day)	50
	D. Unskilled rural wage (Rp/8-hour day)	5,000
V.	Processing costs (Rp/mt of dry cane)	1,200,000
VI.	Market value of land (Rp/ha)	188,000
VII.	Financial price of rattan	
	A. Green cane (Rp/mt)	350,000
	B. Processed cane (Rp/mt)	1,754,384
VIII.	Nominal scrap value of palms in year 24	26,177,948
IX.	Shadow prices	
	A. Rattan (Godoy and Ching Feaw 1989a)	
	1. Green cane (Rp/mt)	331,408
	2. Processed cane (Rp/mt)	1,657,347
	B. Wage: same as financial wage	
	C. Premium on foreign exchange (%)	10
	D. Opportunity cost of capital (%)	10
X.	Real Growth rates (%/p.a.)	

	A.	Discount rate	10
	B.	Wages	2
	C.	Price of Rattan	0.18
XI.	Total seedling nursery costs (Rp/ha)		37,514

Except for rattan, we did not find evidence to suggest that the financial and the shadow price of other inputs or outputs differed because the most important factors of production (e.g. labor) for rattan cultivation are composed of non-tradables and are not subject to distortions. The treatment of the shadow price of land is discussed below. Farmers do not use tradeable inputs which could introduce a divergence between financial and economic prices (e.g. fertilizers, pesticides, fungicides). We applied the same discount rate in the economic analysis as in the financial analysis. The methodology for estimating the shadow price of rattan is described in Godoy and Ching Feaw (1989a). A 10% foreign exchange premium was added to the value of the output to adjust for the overvalued exchange rate. This premium is derived from Godoy and Bennett (1989).

Financial analysis

Green Canes. The results of this study suggest that the cultivation of *irit* and its sale in the green, unprocessed state yields a NPV of Rp 828,000/ha (1US$=1,675 Rupiahs (Rp)) and an IRR of 21% (Table 2). These favorable results hold despite the lower farmgate prices prevailing after the export ban of Indonesia; the ban depressed farmgate prices by 30%-50%. This level of profitability is comparable to the returns from smallholder cultivation of monocrop hybrid coconuts with good management in ideal growing conditions (Bennett and Godoy 1989).

Table 2: Results of Financial and Economic Analses for Rattan *Irit* Cultivation and Processing (Real Discount Rate=10%)

	Green	Processed
Financial		
NPV (Rp)	828,167	946,091
IRR (%)	21.0	22.1
Economic		
NPV (Rp)	728,31	825,967
IRR (%)	21.0	22.0

The smallholder cultivation of rattan would still generate a financial surplus using a real discount rate of 10% despite large changes in the value of key variables (Table 3). Rattan cultivation would remain profitable to smallholders if any of the following variables changed independently: the real discount rate doubled, the market land value increased five-fold, yields decreased by half, or farmgate prices dropped by 35%.

Table 3: Break-Even Values for Key Variables Which Set NPV=0
(Real discount rate = 10%)

			Break-Even Values			
			Financial		Economic	
	Variable	Base Case	Green	Processed	Green	Processed
[1].	Green rattan price ('000 Rp/mt)					
	First grade	400	253	203	227	198
	Second grade	350	221	178	199	173
	Third grade	300	189	153	170	148
	% price drop		36.7	49.1	34.0	42.4
[2].	Real rattan price growth p.a.(%)	0.178	-2.57	-3.91	-2.32	-3.14
[3].	Daily wage ('000 Rp/day)	5	14.0	22.4	12.9	20.2
[4].	Real wage growth (%/pa)	2.00	5.34	7.43	5.03	6.45
[5].	Net green cane yields at maturity (mt/ha/year)	1.47	0.59	0.18	0.62	0.20
[6].	Cane growth rate (m/year)	4.00	1.6	1.0	1.7	1.1
[7].	Harvesting costs Rp'000/100 kg of green cane	10	19.4	--[a]	18.2	--
[8].	Land market value (Rp '000/ha)	188	1073	1215	990	1097
[9].	Real discount rate	10	20.20	21.27	20.1	21.17

[a]. Not applicable because with processed canes harvesting costs are replaced by the foregone sales of green cane.

Processed Canes. If farmers wash, sulphur fumigate, split, and sun-dry canes locally instead of selling green canes, private profitability increases. In calculating the private profitability of processing we charged the foregone sale of green

canes as a cost to the farmer; by selling processed canes, farmers forfeit the benefits of selling green cane, and these foregone sales must be charged as an opportunity cost to farmers who process canes. The incremental NPV and marginal IRR for cultivating rattan and selling processed canes reach Rp 946,000/ha and 22%. The data in Table 3 shows that processing canes would generate a positive NPV despite significant changes in the value of key variables.

It is not clear why farmers opt to sell green cane instead of producing the more profitable processed canes; it is also not clear what percentage of the population chooses each of these options. The health hazards associated with processing may induce some smallholders to sell green cane instead of selling the more profitable processed rattan (see below).

Economic Analysis

The economic returns for rattan cultivation are slightly lower than the financial returns partly because we used conservative estimates in the economic analysis. For example, we did not find any distortions between the financial and the shadow rural wage or land value. We assumed, conservatively, that rattan cultivation did not produce any positive environmental externalities. In fact, rattan cultivation requires arboreal support and therefore provides an incentive to maintain secondary forest cover, thereby providing downstream ecological benefits. We also did not assume that the cultivation of rattan produced any negative environmental externalities in the form of loss of biological diversity of trees that must be thinned to plant rattan. Had we followed the World Bank in assuming that the shadow rural wage in the Outer Islands is only 80% of the financial wage or had we imputed benefits to the enhanced stability of land use brought about by the cultivation of rattan, then the economic returns would have increased. Even under our conservative estimates, however, rattan cultivation yields unambiguous net economic benefits to the nation.

Green Canes. The cultivation of rattan and the sale of green canes generates a NPV of Rp 728,000 and an IRR of 21%. The data in Table 3 indicate that the social profitability of rattan cultivation and the sale of green cane would hold using a real economic discount rate of 10% even if less favorable market conditions prevailed over a number of important variables.

Processed Canes. The cultivation of irit and the sale of processed canes yields a higher economic NPV and marginal IRR than the production of green canes. The NPV and marginal IRR reach Rp 825,000/ha and 22% under these conditions assuming the economic cost of capital is kept constant at 10%. The ban would have to depress world prices by 35-49% before the NPV turned

negative.

The economic benefits of downstream processing are probably lower than these figures suggest because sulfur fumigation may lead to fatal respiratory diseases, which we did not take into account in our calculations. Sulfur burning produces two highly toxic fumes, sulfuric oxide and hydrogen sulfide (Godoy and Ching Feaw 1989a). We interviewed farmers who refused to process canes because of health risks. Villagers claim that about a dozen people died in recent years because of respiratory diseases associated with rattan processing in the village.

EXPANDING SMALLHOLDER CANE PLANTATIONS IN THE DEVELOPING WORLD

The four principal rattan producing countries -- Indonesia, Malaysia, Philippines, and Thailand -- have banned or applied high export taxes on raw and semi-processed canes, thereby raising world prices. For instance, Indonesia's recent ban has caused world prices to increase by 20% (Godoy and Rodrik 1989). The increase in world prices for unprocessed rattan allows minor producers of canes an opportunity to expand exports of canes through greater collections from the wild and through the establishment of smallholder plantations.

Export restrictions on rattan by the major exporters have encouraged non-traditional producers to begin exporting canes. Several marginal producers, such as Papua New Guinea, now export unprocessed canes owing to the lure of higher world prices. Several Central American nations have also started to explore the potential for expanding exports of unprocessed canes.

A study by Godoy and Rodrik (1989) suggests that a conservative estimate for the world price elasticity of demand for raw and for semi-processed rattan ranges between -1.6 and -2.0. Rattan competes with numerous substitutes, including other canes, woody products, plastics, and metals. Increased supplies of rattan will therefore not have much of an adverse effect upon world prices.

Owing to the favorable world market situation, developing countries and international development organizations have begun to explore the potential for expanding exports of rattan or of canes that can substitute for rattan. A strategy for promoting the exports and the cultivation of canes should involved the following steps:

[a]. Identify canes that are currently used in the local economy to manufacture furniture. Countries such as Nicaragua, Peru, and Costa Rica, for instance, have well-developed

traditions of manufacturing furniture with canes from the local forest. Having identified these canes, samples should be sent to furniture manufacturers in Asia, Europe, and the USA to determine their value in the international cane furniture market.

[b]. If there is an international demand for these products, governments should export these canes in their unprocessed form. Efforts to move into downstream furniture manufacturing by restricting exports of unprocessed canes should be avoided, as they are costly to the nation (Godoy and Rodrik 1989).

[c]. A policy of promoting the exports of a lucrative non-timber forest product can lead to the depletion of the resource. Several of the more valuable species of rattan face extinction in Asia because governments have not promoted policies to encourage their conservation and cultivation nor have governments provided the appropriate tenurial incentives to encourage smallholders or the private sector to cultivate these goods.

Therefore, countries endowed with canes of export value should design policies to encourage the cultivation of these canes at the same time that they promote the exports of these goods from the wild. To encourage the cultivation of canes governments must insure that smallholders have secure tenure to forest plots. Governments must also establish trial plots of canes in secondary forest. Trial plots will allow scientists and farmers to judge the ecological and the economic suitability of cultivating canes either as a monocrop in secondary forest or as an intercrop with tree crops or fruit trees.

This strategy for promoting cane cultivation involves a short and a long-term vision. In the short run, countries must encourage the exports of unprocessed canes which have commercial value. In the long run, governments must provide security of tenure and determine whether canes can be cultivated. 5-10 years in the future, if trial plots suggests that the cultivation of canes is financially lucrative and ecologically benign, governments and development organizations can begin designing strategies for promoting the smallholder cultivation of these goods.

The strategy outline above faces at least two dangers. First, cane cultivation may prove to be financially unattractive to cultivate even with secure tenure. Policies to encourage the exports of these canes could therefore lead to the depletion of natural stocks without inducing farmers or the corporate sector to undertake cultivation. If this scenario materializes, governments must evaluate the benefits and costs of providing a subsidy to cane cultivators. Since cane cultivation probably provides net positive externalities, a producer subsidy could be justified on economic grounds. Second, the major rattan

producers could relax or lift their export restrictions on rattan, thereby increasing world supplies and lowering world prices for unprocessed canes. Lower prices would reduce the incentive for marginal producers to continue exporting canes. Although this could happen, the evidence suggests that governments rarely rescind policies designed to restrict exports of natural resources because of the political costs of such a policy shift.

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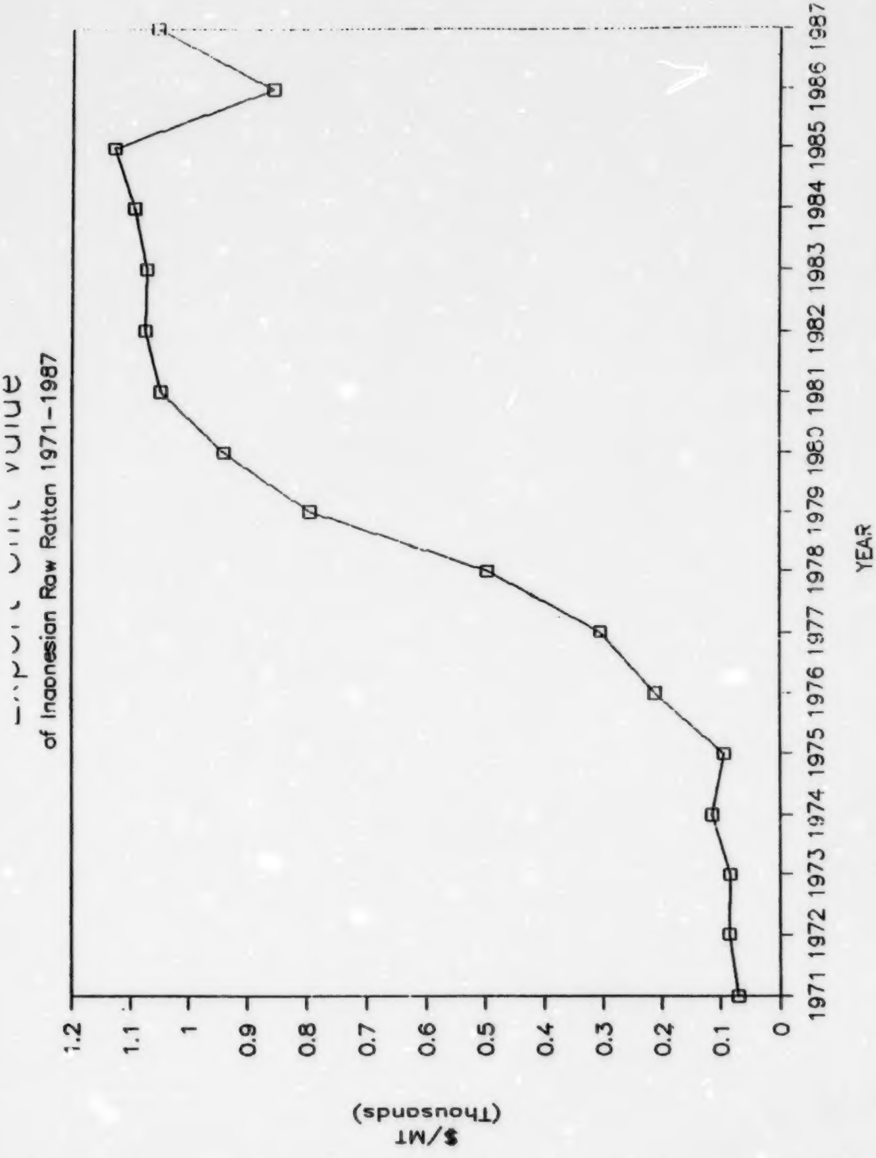
Figure 1


of Indonesian Raw Rattan 1971-1987
$/MT
(Thousands)
YEAR
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987

MARKET AND TRADE STRUCTURE OF THE PHILIPPINE RATTAN INDUSTRY: IMPLICATIONS FOR POLICY

Isabelita M. Pabuayon

Assistant Professor
Department of Agricultural Economics

College of Economics and Management
University of the Philippines at Los Banos
College, Laguna, Philippines

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SUMMARY

The Philippine rattan industry is characterized by a limited degree of seller concentration, considerable product differentiation, and increasing entry barriers - high capital and skill requirements and scarcity of raw materials. Sales and profit rates are higher among bigger firms but there is no strong indication at present that they cause undue disadvantage to smaller firms. However, positive measures to address the problems must be undertaken immediately and more aggressively to maintain tne country's competitiveness in the world market. If constraints are left unchecked, the small and high-cost firms could be adversely affected. Greater efficiency and development of domestic raw material sources are the viable options for the industry.

Keywords: Market structure, conduct, performance, efficiency

INTRODUCTION

The remarkable growth of the Philippine rattan industry since the 1970s manifests the country's modest success in pursuing employment-oriented development strategies. The industry provides jobs to thousands of Filipinos that include the rattan gatherers and suppliers, the manufacturers consisting of small-scale producers and large export-oriented enterprises, the factory workers and weavers, and the traders of rattan products who serve both domestic and foreign markets.

To a great extent, the performance of an industry and its contribution to economic welfare is determined by the market structure and the resulting behavior of the participating firms. This paper attempts to relate the market and trade structure of the Philippine rattan industry to its performance. It also draws policy implications which both the government and private sectors should consider for enhancing the contribution of the industry in achieving sustainable growth and welfare objectives.

THE S-C-P APPROACH FOR ANALYZING THE RATTAN INDUSTRY

The market structure, conduct and performance (S-C-P) approach provides a useful framework for analyzing the outcomes of the business activities of rattan firms in relation to social and economic goals. Market structure refers to the characteristics of the market environment that influence the behavior of firms. The latter is referred to as market conduct which consists of the policies that firms adopt with respect to pricing and output determination. Conduct is linked to performance - an evaluation of the extent to which the economic results of the industry's behavior deviate from the best possible contribution it could make in maximizing economic welfare (Caves 1982). Theory and empirical evidence suggest that firms in non-competitively structured markets are able to exercise extensive market power resulting in higher prices, large profits, and inefficiencies (Marion *et al.* 1979).

Primary and secondary data were used in the analysis. The former were collected through actual interviews of manufacturers and traders of rattan furniture and handicraft in major production areas of Luzon and Cebu. Secondary data were gathered from government and research agencies. During the study period, the currency exchange rate was ₱20.00 = U.S.$1.00.

MARKET STRUCTURE AND CONDUCT

Profile of Rattan Manufacturers

As of 1986, registered rattan firms numbered 357 of which 300 are in furniture manufacturing and the rest in handicraft making. About 70% are in Metro Manila and Cebu. Not accounted for are many unregistered small producers who also contribute significantly to the economy.

The 48 furniture manufacturers surveyed were classified into the following categories: small with less than 200 workers/employees, medium having 200-300, and large with more than 300. Grouping for the 42 handicraft firms is as follows: small with less than 50 workers, medium with 50-100, and large with more than 100. About half of the respondents are small firms. The average number of workers was 307 and 81 for furniture and handicraft, respectively. Most furniture factories follow assembly-line method of production. In contrast, handicraft makers maintain a limited number of in-house workers with majority of their output sub-contracted to community members who usually work in their respective homes. Furniture firms also engage in sub-contracting.

The furniture firms are mostly corporations and direct exporters. The small ones either sell to traders who have direct link with importers or cater only to domestic market. Handicraft enterprises are usually operated by single proprietors with bulk of output also directed to foreign buyers through trader-exporters.

Structural Characteristics

The structure of the market influences the nature of competition, pricing and output determination within the industry. A highly concentrated industry wherein the bulk of the output is controlled by a few firms may exhibit implicit or explicit forms of collusion to raise prices and profits above the competitive level. Similarly, the relative ease or difficulty of entering or leaving the market determines the number of potential rivals and therefore the extent by which interdependent action among firms is possible. The ability of firms to differentiate products may offer distinct advantages in expanding market share and also act as barriers thus limiting competition.

The rattan industry is characterized by a limited to moderate degree of seller concentration with four-firm concentration ratio (CR_4) of 22% and 41% for the furniture and handicraft, respectively. Concentration ratio is the total of the market shares of the top firms in the industry. A highly concentrated industry has CR_4 of at least 60% (Marion *et al.* 1979). Using 1986 export value, CR_4 was 21% for furniture and 8% for handicraft.

The recent increase in the number of firms and capacity expansion in response to the growing market suggests that the industry is not characterized by high entry barriers that could

be observed in oligopolistic industries. This does not, however, imply that entry or exit is completely easy since high capital and skill requirements and scarcity of raw materials nowadays are major considerations in establishing a rattan business. Comparatively, more small firms reported the problem of raw materials which implies the greater difficulty on their part to secure these materials relative to the larger firms. Nonetheless, the existence of small firms alongside large firms indicates some degree of competition. The rising production cost due to raw material constraints, however, will pose serious difficulty to smaller firms unless cost-reduction measures in the use of other inputs are adopted.

Considerable product differentiation exists in rattan manufacturing. Furniture products vary widely in kind, function, design, size, shape, and overall quality. Handicraft similarly exhibits large differences in types (baskets, hampers, lampshades, planters, bathroom accessories); shapes (oval, pyramid, round, rectangular, heart-shaped); and unit of sale (per unit or per set). Other variations arise from the rattan species used, type of finish, color whether natural or dyed, and whether furniture is knocked-down or fully-assembled.

Product and Pricing Policies

The existence of many firms in the industry and its export-oriented nature requiring quality standards demand product and pricing policies appropriate for maintaining competition within the industry. Output determination is largely through purchase orders of specified volume and quality and other trade specifications including packaging, shipment and delivery date. All these factors are incorporated in the pricing formula, hence, a wide range of prices exist for rattan products. Because the rattan market is a consumers' market, considerable effort is made to meet buyers' specifications, even maintaining adequate inventory for responding to immediate demand, including promotional strategies. During peak demands and when orders are made on short notice, adaptation mechanisms include hiring additional workers, encouraging overtime work and sub-contracting. These were observed in large and small firms alike.

INDUSTRY PERFORMANCE

Foreign Exchange Generation

The expansion of the industry attests to the high revenue potential of rattan manufacturing. Since rattan products are largely export-oriented serving more than 50 countries, the industry contributes greatly in foreign exchange. For 1987, the furniture exports amounted to U.S.$94.9 million, up from only U.S.$1.8 million in 1973 (Figure 1) with annual growth rate of 14% and 33% in quantity and value during this period. Rattan has also dominated all other furniture exports of the country.

Understandably, the larger firms exhibited greater sales than smaller firms (Table 1). Profit rates are also higher among the bigger furniture firms. Sales are mainly determined by the volume of rattan utilized, workers employed, and years in business (Table 2). When the two major inputs (labor and raw materials) become limiting, the viability of the industry is threatened. Likewise, older and established firms may have some advantage in sourcing raw materials, attracting skilled workers, having regular buyers, and having achieved the desired managerial maturity for efficient conduct of business operations.

Capacity Utilization

On the average, the firms were slightly short of full capacity utilization (Table 1). Some firms, though, have come close to full capacity while a few were over-utilized. The data shown, however, do not reflect the extent of utilization for a sufficiently longer period nor for an adequately large sample to provide definitive conclusions. Interestingly, the proportion of firms who reported the problem of raw materials was higher among the smaller firms whose capacity utilization was relatively lower.

The industry's relatively high utilization rate reflects its ability to make the adjustments needed to cope with the raw material problem. In order to take advantage of the expanding demand, firms have resorted to importation of poles and splits, using low grade poles and bleaching them, and combining rattan and other materials that are more readily available (De la Merced 1988).

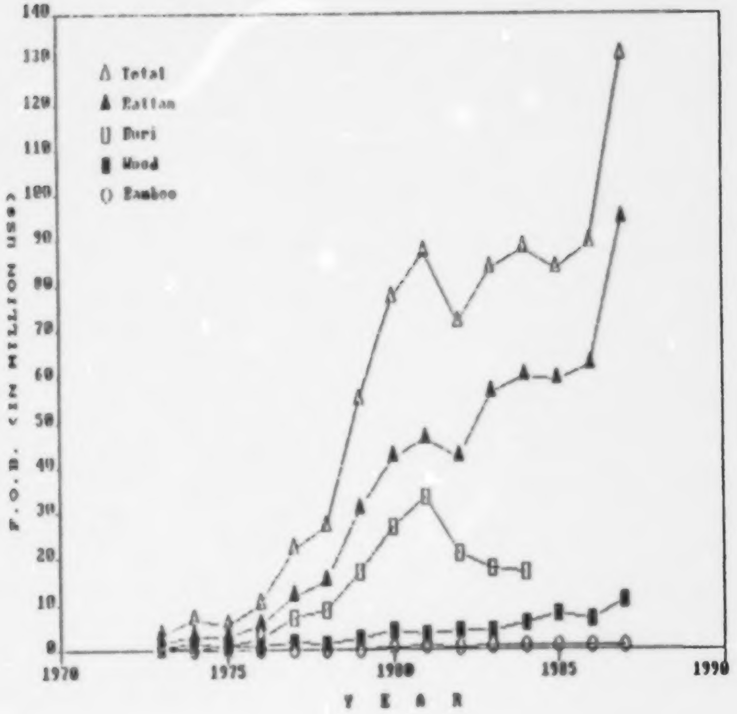

Figure 1. Total furniture exports, Philippines, 1973 - 1987.

Table 1. Average capacity utilization, sales and profit rates by firm size, Luzon and Cebu, 1986-87.

ITEM	FIRM SIZE			ALL
	Small	Medium	Large	
<u>Furniture</u>				
Cebu				
Capacity utilization (%)	79	113	90	90
Sales per month (₱'000)	743	1,901	3,067	1,687
Profit rate (%)[a]	9	44	47	38
Luzon				
Capacity utilization (%)	98	83	95	92
Sales per month (₱'000)	399	2,659	5,015	1,209
Profit rate (%)[a]	53	84	-	59
<u>Handicraft</u>				
Capacity utilization (%)	88	134	87	90
Sales per month (₱'000)	97	105	426	195
Profit rate (%)	34	18	32	32

[a]Income before tax as percent of total cost.

Table 2. Regression results[a] showing the relationship between firm sales and various factors (in double-logarithmic form), 85 rattan manufacturers, Luzon and Cebu, 1986-87.

ITEM		REGRESSION COEFFICIENT	T-RATIO	PROBABILITY
Furniture				
Dependent variable: Sales/month				
Explanatory variables:				
Years in business		.2928	2.075	.0439
Number of workers		.7349	9.402	.0000
Rattan utilized (l. m.)		.2109	2.460	.0179
Constant		3.0722		
R^2	.82			
F-ratio	71.10			
n	48			
Handicraft				
Dependent variable: Sales/month				
Explanatory variables:				
Years in business		.2743	3.157	.0034
Number of workers		.2264	2.836	.0077
Rattan utilized (₱/month)		.7994	6.666	.0000
Constant		.9266		
R^2	.77			
F-ratio	41.21			
n	37			

[a] Estimated using ordinary least squares (OLS).

Employment and Wages Paid

Furniture firms paid their workers better wages than handicraft firms, at ₱49.73 and ₱35.70 per worker per day, respectively. The corresponding legislated minimum wage rates in 1986 were ₱56.00 - 57.08 for non-agricultural workers and ₱35.67 and ₱46.67 for non-plantation and plantation farm workers, respectively. Thus, the furniture workers were paid lower wages than their non-farm counterparts but the wages of handicraft workers approximated only the lower wages of non-plantation agricultural workers. By firm size, the larger firms paid slightly higher wages than the small firms. This may explain why there are relatively more small firms which reported the difficulty of attracting skilled workers.

Progressiveness

In general, the industry appears to have achieved a respectable rate of progress in terms of developing production techniques and attaining a high level of craftmanship in handicraft and furniture manufacturing. The expanding demand for Philippine products indicates that we are able to compete favorably well with our foreign counterparts in selling products which meet international quality standards. Various research and development efforts on processing and utilization are underway in government and private sectors but there is still much to be done (Tesoro 1987). In the final analysis, the consumers are the beneficiaries of whatever improvements the industry can achieve in R and D. It is clear that a wide variety of rattan products of varying designs and qualities with corresponding price differentials are now available. All these add up to consumer satisfaction - perhaps the real test of performance.

Various initiatives have also been undertaken, though on a limited scale, to address the raw material problem. Some 5,000 hectares of commercial rattan plantation had been established in 1983 by the private sector. Research relating to rattan production including propagation, cultivation, fertilization and management are in progress (Pollisco and Lapis 1988).

POLICY IMPLICATIONS

The structure of the rattan industry is such that there is a limited seller concentration with a large number of firms and a high degree of product differentiation. Since competition

generally exists, mostly in non-price forms, small firms exist alongside large firms and even high-cost alongside low-cost firms. There is no indication that any single seller or a small group of sellers could perceptively influence price and output levels so as to cause undue disadvantage to the remaining sellers. However, there are increasing barriers to entry and exit due to the large capital and skill requirements and the growing scarcity of raw materials.

While the performance of the industry in generating revenue and employment is generally satisfactory, the problems associated with the dwindling supply of raw materials and general economic conditions pose considerable constraints to fully exploring the industry's potentials. Undoubtedly, the world rattan market is growing due to rising income levels and increasing preference for rattan products. The challenge for the country is to maintain its established markets (even tap new ones) in the face of threats from competitors. Maintaining competitiveness requires greater efficiency in production and sustained efforts in product development and promotional strategies. If left unchecked, the inadequate supply of raw materials would cause underutilization of factories with consequent escalation in cost and selling price.

Presently, there is no strong evidence to suggest that larger firms place the smaller firms in a weak bargaining position in terms of sourcing basic inputs and securing market outlets. However, there may be economic dislocation among small firms and even large but high-cost firms in the long-run if the problems are not addressed.

There is apparently an increasing difficulty of attracting skilled workers. While this may result from lack of information in the labor market, opportunities for training of workers should be provided. Unfortunately, some workers do not even receive the minimum wage reflecting low labor productivity and financial constraints affecting some firms.

For equity considerations and even greater competition, new entrants and smaller firms should be assisted through adequate market information and viable financing schemes particularly to provide them opportunities for export trading.

More aggressive efforts should be pursued in plantation development through greater incentives for the private sector and research and extension support from the government. Trade policies in other countries have shut off supplies of raw materials which puts even more pressure for developing domestic sources and finding efficient methods of harvesting, handling, processing, and utilization of available resources.

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RECENT PROGRESS IN RATTAN TRADES, INDUSTRY AND RESOURCE DEVELOPMENT IN INDONESIA

Toga Silitonga [1], Hendro Prahasto [2] Soetarso Priasukmana [3]

1) and 2) Senior researchers ,
Forest Products Research and Development Centre, Bogor.
3) Director, Forestry Research Institute, Samarinda

Agency for Forestry Research and Development, Indonesia

FDC: 287: 741: 72: (910)

SUMMARY

Although Indonesia has the world's largest resource of rattan (over 85% of the world market), it is less known in the international fora. For several decades, most of its rattan exports were in raw unprocessed form, giving up the added value shares to the re-exporting countries. Recently, the government of Indonesia has taken steps to minimize the export of raw rattan and encouraged both domestic and foreign investments in rattan-based industries. This action was taken aimed at increasing revenues from non oil export and to provide more employment opportunities for its growing population. Continue rattan exploitation from the natural forest with minimum replenishment of the resource is feared to give short supply for the current and future production requirements. Plantation trial by rattan collectors has been started for many years but only recently the forest economists and the desicion makers realize socio - economic importance of rattan for the people. This paper appraises these phenomena in details.

Keywords: Rattan trade,manufacturing, cultivation

I N T R O D U C T I O N

Rattan is the most important non - wood products, and socio - culturally most important palms in Indonesia. Over 9.36 million hectares out of 143,9 million hectares of its forests have been identified as potentially productive rattan forests. Of the 13 genera and more than 600 species record in the world, 8 genera and 350 species are found in Indonesia (Dransfield 1979), capable of producing 600,000 tons (dry weight) per year. Of which it was assessed that 250,000 tons could be produced from the natural forest on a sustainable basis (Table 1). For many years period to 1988, exports of raw rattan and semi - finished products from Indonesia, in terms of volume has been between 80 and 90 % of the world's rattan trade. However, its share of the global finished product market has been meagre.

In the past, rattan - based industry was only a rural - based labor intensive industry. Given the existing technology, the quality of the product was hardly capable of competing with those produced in the re - exporting countries. Until 1983, the number of people engaged in rattan cutting, processing and trades were less than 100,000 and around 17,000 of them involved in rattan handicraft activities and trades (Silitonga T 1985). Recently, rattan trades and industry have been augmented manifolds.

Although the rattan cultivation has been started as early as 1850, till today most of the commercial rattan comes from the natural forests. Rattan plantation history in Indonesia was started when *sega* rattan (*Calamus caesius*) and *irit* (*C. trachycoleus*) were first cultivated in Kalimantan by shifting cultivators (Heyne *in* Yudodibroto 1983). The rattan seedlings were usually planted with the last crops, leaving them to grow naturally for future harvest. Meaningful reinvestment in rattan cultivation was practically none.

To alleviate the postibility of diminishing supply from the natural forest, and to cope with the growing demand of the industry, the Government of Indonesia is harnessing rattan farmers and state forest enterprises by enunciating several policies regarding rattan exploitations, processing and industry, trades and cultivation. Raw rattan exports were banned in 1979 (Menteri Perdagangan 1979). Followed by the rattan industry growth, beginning September 1, 1988 the export of semi - finished product was prohibited (Menteri Perdagangan 1988). Recently, the Minister of Forestry issued a simplified procedures

for rattan cultivation (Menteri Kehutanan 1989) to stimulate the development of rattan - based industry and trade, and rattan resource development in Indonesia. This paper attempts to explore prospect for development and reserch needs.

RESEARCH METHODOLOGY

Assesment of Trade, and Industrial Development

This two-week study was conducted through field survey to several rattan trades and processing centers in four locations in Jakarta, Cirebon, and Surabaya (all in Java island), and in Banjarmasin of Kalimantan. Literature surveys were also conducted to obtain secondary data from Central Bureau of Statistics (CBS), Foresry Department, and from the Department of industry. Recent development information in trade and industry was obtained from the Furniture Makers and Handicrafts Association (ASMINDO), Jakarta. The impact of new trade policy in rattan industry and socio - economic development were also assessed with a case field study in Tanjung Redeb of East Kalimantan.

A descriptive analysis and cross tabulation methods were made to vizualize the growth of rattan industry, trades and employment opportunities in the country.

The Economics of Rattan Cultivation

This study was conducted through literatures review on rattan cultivation in Java, Kalimantan. Sizable information concerning rattan cultivation was obtained from various places in Central Kalimantan, East Kalimantan, West Java. Most of the cultivation data in this paper are from published sources (Soetarso P 1986)

COMMERCIAL AND INDUSTRIAL DEVELOPMENT

Rattan is considered a minor forest products (6 - 9%) compared to timber (CBS 1988). Over several decades period to 1987, Indonesia had been a leading in raw rattan export. Statistical records indicate that rattan harvest of Indonesia was fluctuated around 120,000 tons (dry weight) per year

(1Silitonga T 1985). Most of this product comes from natural forests. The most potential areas are West Sumatra, most Kalimantan, Central and South Sulawesi. Irian Jaya is expected to be a potential area, but due to the lack of infra structures rattan from this area still remain untouched (Table 1).

Table 1. Estimated Rattan Forest Area and Production Potential by Principal Islands.

Island	Rattan Forest Area, 000 Ha	Estimated Production Potential (Ton/Yr)	
		Commercial Species	All Species
Sumatra	699	65,000	146,840
Java	N.A	N.A	N.A
Bali & Nusa Tenggara	N.A	7.000	38.000
Kalimantan	5,035	80,000	135,150
Sulawesi	3,635	68,000	255,400
Maluku	N.A	10,000	N.A
Irian Jaya	N.A	20,000	N.A
INDONESIA	9,359	250,000	573,390

Source : Department of Forestry, Directorat General of Forest Industry, 1989

At present, about 250,000 tons (dry weight) per year are assessed to be commercial giving 80 to 85 % of Indonesia rattan share in the world market. The rest 15 to 20 % at equal proportion comes from the Philippines, Thailand, and Malaysia. Mexico, China, and others, are accounted for 2.2 % shares (Menteri Kehutanan 1989).

Rattan production trend from 1982 to 1987 clearly indicated (Table 2) that production from most principal islands continue to grow, and the peak was in 1987 amounted to 143,447 tons. This amount is about 60 % over the normal production level. The rattan export of Indonesia is expected to continue its dominant role not only in trade volume, but more importantly the revenue it can generate.

Table 2. Rattan Production (Tons/Yr) 1982 - 1988

Island	1982	1983	1984	1985	1986	1987	1988 +)
Sumatra	29,250	31,844	37,050	38,750	54,631	45,550	16,870
Jawa	3,651	4,664	7,675	6,624	6,275	16,454	-
Bali & Nusa Tenggara	3,150	2,140	760	1,350	4,110	4,690	1,870
Kalimantan	38,100	40,780	45,230	43,000	63,400	54,600	8,470
Sulawesi	38,600	48,260	50,598	47,892	54,640	47,560	40,705
Maluku	500	1,366	-	60	870	97	170
Irian Jaya	180	100	320	117	136	-	-
INDONESIA	113,431	129,154	141,943	137,738	183,942	168,854	-

Source : Extracted from Menon, 1989.
+) Production up to June 1988

World trade of rattan is estimated at USD 600 - 800 million/year (Menon K D 1989). In 1979 (the year when export of raw rattan banned), 87,271 tons of rattan valued at USD 57.99 million were exported or equivalent to 7.2 - 9.6 % of the total world trade. At this time, the raw rattan export accounted for 84 %; semi - finished rattan accounted for only 15 %; and the share of finished product was only 1 % in volume. Realizing this situation the government of Indonesia has interest to increase it share by introducing rattan industry. By 1986 the export of rattan rose to 106,972 tons valued at USD 104.89 million. At this time the export of semi - finished rattan products accounted for 85 % of the total exports in that year and 72 % of the value. The export of finished products in the same period had risen to 2 % by volume and 15 % by value.

In 1986, export of rattan was 96% accounted for semi - finished and 4 % of finished products. Most of the finished - products (dominated by weaving, webbing, and basketary) went to Hongkong, Taiwan, and Singapore which accounted for 80 to 90 % by volume, and the others went to 30 other different countries. This was a big turning point of rattan industry in Indonesia. Aware of this fact, the government of Indonesia announced its intention to halt the export of semi - finished product by January 1989 which then back -forwarded to September 1988.

These new policies has stimulated rattan industry to grow manifolds. From Indonesian side this was viewed as enormous technology transfer. On August 11, 1988, Indonesia dedicated the operations of 100 new rattan processing plants and 124 handicraft centres in 22 Indonesian provinces, making up the total of 381 industrial units capable of producing 438,960 tons products per year (Menon K D 1989). By the end of 1988, the USD 80 million earnings out of USD 1 billion of estimated world rattan trade transaction, Indonesia has increased export value to a total of USD 194.606,579 by exporting less rattan material of 85,223 tons (CBS 1988).

For many years, Indonesia has been the major supplies of raw material to the rattan furniture industries of re - exporting countries in the Far East. Now it is well paving the way to becoming the world's largest exporter of finished rattan products, putting more added value to its resources.

Table 3. Rattan exports and price development for 1983 to 1989+)

Year	Volume (Tons)	Total Value USD	Average USD/Ton
1983	81,979	85,686	1,045.22
1984	90,638	93,224	1,028.53
1985	89,337	97,055	1,086.39
1986	109,555	109,547	999.93
1987	143,447	211,607	1,475.16
1988	85,223	194,067	2,277.17
1989	25,221	87,185	3,456.84

Source : Extracted from CBS, 1988 and Forestry Department.
+) Export up to June 1989

There was a significant price increase per unit weight after the semi - finished product was banned for export. Since then, Indonesian's rattan industry began to grow rapidly.The number of manufacturing units increased from 109 in October 1986 to 381 in December 1988.

Table 4. Employment and investment in rattan industry, 1988

Rattan Industry	Unit	Before Oct.1986	Additional units	Dec.1988
No. of Industry	Unit	109	272	381
Capacity :				
Raw rattan	tons	44,942	4000	48,942
Semi - finished	tons	230,998	241,901	472,899
Finished	tons	61,177	377,782	438,959
Investments	USD 10^3	59,842	368,454	428,296
No. Employment	person	22,688	130,107	152,795

In two - year period investment in the industry soaring from USD 59,842 million to USD 428.30 million with an increase in employment from 22,688 to 152,795 in the same period. Data obtained from our field survey revealed that most of the industries work under the design capacity due to limited domestic and foreign markets of finished products. As a result, raw rattan price drops significantly and several rattan collectors in Tanjung Redeb, the area surveyed, becoming temporarily unemployed. Now the question is how to preserve the rattan for future requirement. The resource development becomes an important and interesting subjects to work out.

RATTAN RESOURCE DEVELOPMENT

Continuing high rate of rattan resource depletion in Indonesia due to high rate of harvesting or by deforestation calls for urgent renewal of the resource. Traditional method which have been practiced by rattan harvestors for many years was felt unsufficient to cope with the high rate of utilization. The Indonesian government has seriously guarded the preservation of rattan resources. Actions to augment supplies from natural resources through rattan cultivations are needed to arrest the over - exploitation of the natural supply sources.

To establish rattan plantations, considerations must be given to several factors such as the status of knowledge regarding the chosen species, silvicultural techniques, site suitability, and most of all its socio - economic value. It is the fact that rattan cultivation technique has been studied and most of the major rattan producing countries are encouraging plantations. To day, man made rattan plantations accounted for 21,536 hectares, where Indonesia reported total plantations area of 13,000 hectares, the rest in the Philippines , Malaysia, and Thailand (Menon K D 1989). New *Sega* rattan (*Calamus caesius*) plantations have just been estabilished 1,100 hectares in Buan by the Inhutani, a forestry state corporation, and 500 hectares in Kahold, both are located in East Kalimantan (Soetarso 1990). The size of rattan plantations is expected to reach 1.25 million hectares over the next 10 years.

It is anticipated that the target point could well be achieved by at least through one of the following methods : 1) establishing large - scale plantations by state corporation, 2) smaller - scale under a Nucleus Estate Smallholder, 3) small scale forest fringe plantations by forest dwellers living within or at the fringes of forests, 4) Large - scale plantations in logged over or conversion forests, to be estabilished by the public and / or private sectors. Before embarking on such activities, it is important to carefully examine the plantation costings and the economic viability of such undertakings.

Plantation Investments

Cost elements involved in estabilishing rattan plantations are mainly nursery and seedling preparation, site clearing, and planting and maintenance. Time and periodicity of flowering and fruiting scheme vary with the species of rattan, and with locality. Rattan seeds particularly *Calamus manan* have short dormancy and can not be stored in dry condition without loosing their viability. These factors have to be considered as it will directly effect the unit cost of seedlings.

Cost of seedling express in Indonesian Rupiah (IDR)+) near the collection site recorded was IDR 10/piece for most small diameter canes (*sega, irit* etc.), and IDR 25/piece for seedling of large diameter cane. Transportation cost to the planting site varies according to distance but IDR 25/unit and IDR 50/unit in

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+) IDR 1790 equivalent to USD 1.00

planting site for small and large diameter rattans are reasonable prices at this time. Total costs of seedlings per unit plantation area will be directly effected by plant spacing and species. Plant spacing usually 4 by 4 meter to 8 by 15 meter depending upon the suckering behaviour of the species concerned. For small diameter rattan the cost of seedlings can be variable from IDR 5,000//ha *sega* to IDR 10,000/ha for *putih* rattan.

Site preparation, line clearing, and digging planting holes, normally size 20 X 20 X 10 Cm for one hectare requires 20 man days at IDR 3,000/day. Transplantation of seedlings from nursery to the field and maintenance of the young plantation requires 7 man-days per hectare at the same rate as for the site preparation.

Based on past experiences, mainteanance cost from seedlings to mature plantation was rarely made if any at all. A case study conducted by Soetarso was carried out in East Kalimantan using 4 species include *Sega, Jahab, Putih, Merah* rattans, all from small diameter species. In this study the first harvest of rattan can be expected on year ten after plantation, then, every other year thereafter. Production potential varies from 1.70 - 3.90 ton/ha/harvest. The plantation renewal will not be made until after the plantation productivity drop significantly at around 30 years of age. Detail of this study was published (Soetarso 1986).

At harvest time, a rattan collector is able to collect 30 - 50 kg wet weight per day of 100 to 200 pieces of rattans, and the cost per piece of 5 - 7 m in lenght varies according to quality from IDR 100 to IDR 150 / kg wet weight. Before selling, the rattan has to be cleaned. A person can clean 150 - 200 kg / day at cost IDR 20 / kg.

Perhaps the most important outcome of this study is the fact that rattan cultivation could be a viable investment, while the socio -economic consideration will be another advantage especially when dealing with the tropical forest. The sustainability of the forest is heavily depending on the socio - economic condition of the forest dwellers. To give a better idea, the following Table 5 is an exerp of the case study in Kalimantan, using the sales price IDR 250; IDR 225, IDR 250, and IDR 190 / kg air dry weight, concecutively for *sega, jahab, putih*, and *merah* rattans.

Table 5. Result of Economic Analysis of Rattan Plantation in Kalimantan, 1986.

Rattan Species	Net Present Value IDR 1000		IRR %
	10 %	20 %	
Sega	377.5	16.2	21.9
Jahab/irit	257.8	7.2	20.9
Putih	184.3	- 9.8	19.0
Merah	219.4	- 1.8	20.0

The net present values are all positive at 10 % interest rate. When the interest rate increased up to 20 %, only *Sega* and *Jahab* seemed to be feaseable. High Internal Rate of Return (IRR) from 19 to 21.9 % reflects that the investment in small diameter rattan is attractive enough compare to other forest investment project.

CONCLUSIONS AND RECOMMENDATIONS

Rattan trade and Industry

The best available data assesed the resource potential of Indonesians rattan at 573,000 tons per year. Presently this potential is capable of supplying industrial requirement. However, by the time all existing industries operate at full capacity, it is anticipated that the industry will be facing short supply unless more resource from the unsurveyed Irian Jaya and Maluku can be found. The new trade policieissued by the Indonesian Government has induced the industrial growth significantly.

The 1988 statistical record indicates that 381 rattan industries operate at 436,960 ton capacity per annum of finished products, adding 152,000 more employment in rattan business.

The trade share of the global market has jumped sharply from USD 80 million in 1986 to over USD 200 million per year. Target point of Indonesia is 50 % share of the USD 1.00 billion world trade of the existing resources with an increased added value of the finished products.

It is recommendable that intensive resource investory be made by using a more appropriate technique through out the country, with special emphasize on Irian Jaya and Maluku areas.

Rattan Resource Development

Dependency on rattan from natural forest will not be able to guarantee raw material requirement of the growing rattan industry in Indonesia. There fore, the present rate of rattan cultivation needs to be augmented.

Total rattan plantation in the world accounted for 22,636 hectares distributed in four major producing countries i.e. Indonesia, the Philippines, Malaysia, and Thailand. Indonesia has target plantation of 1.25 million hectares over the next 10 years period.

Rattan plantation project could be implemented by at least 4 methods i.e. small holder under a nucleus estate; back yard plantation by forest dwellers, and at larger scales by state corporation and/or by the forest concessionaires.

Study on the economics of rattan plantation has been well covered using small diameter species as model. The venture is economically attractive.

The economic analysis of large diameter species, which require longer investment period, is presently non - available. Such study is needed before embarking on large scale operation.

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INDUCTIVE SPATIAL MODELLING AS A TOOL FOR WILDLIFE HABITAT EVALUATION

Richard Aspinall

Division of Land Use Research
Macaulay Land Use Research Institute
Craigiebuckler
Aberdeen AB9 2QJ

FDC: 156.2: 148.2: 585--015.5

SUMMARY

This paper describes an approach to evaluation of wildlife habitat through prediction of the distribution of animal populations. The method presented is a procedure for inductive spatial modelling based on Bayes' Theorem and is implemented as an analytical function within a Geographic Information System. The method is used for analysis of the distribution of Curlew, Golden Plover, and Red Grouse in an upland area of north east Scotland. Habitat information for the area is derived from analysis of LANDSAT Thematic Mapper satellite imagery and from topographic maps. Potential applications of the method are discussed.

Keywords : inductive spatial modelling, GIS, moorland birds.

INTRODUCTION

Information on the distribution and abundance of wildlife is increasingly necessary with growing concern over conservation interests outside specially designated areas and for integration with land use planning and management. Frequently such information is not available, partly because the capacity for data collection is restricted by existing field survey methods and partly because of problems associated with objectively assessing quality of habitat for wildlife. This paper presents a method for predicting distribution of wildlife from analysis of habitat information. The method is a procedure for inductive spatial modelling and is based on Bayes' Theorem. Successful application of the method achieves three results. It provides an objective method for modelling distribution of wildlife populations; it provides a formal indication of quality of habitat for wildlife; it allows analysis of habitat over extensive areas and permits maximum benefit to be obtained from limited, but properly designed, field survey. The problem addressed in this paper is therefore, to assess habitat quality from analysis of distribution of wildlife.

Part of the solution to this problem lies in application of the methods described within the framework provided by Geographic Information System methodologies. GIS has been used to monitor and assess wildlife habitat (see for example, Stenback et al. 1987; Scepan et al. 1987) although typically this has involved application of habitat quality criteria ('rules') through GIS overlay facilities to identify co-occurrence of the specified conditions. Although overlay provides this ability, there is a more general need for incorporation of improved methods of spatial analysis within GIS (e.g. Abler 1987; Department of the Environment 1987; Openshaw 1987; National Centre for Geographic Information and Analysis 1989). Improved analytical functionality would derive from integration of standard statistical analyses for both data analysis and analysis of error trains consequent on overlaying different datalayers; there is also potential for inductive learning procedures to be integrated with GIS. Such procedures can be used to generate testable hypotheses concerning relationships between spatial datasets (Openshaw 1987) and recently Walker and Moore (1988) have presented an inductive method for analysis and modelling of the distribution of kangaroo populations in Australia. The inductive learning procedure employed by Walker and Moore is is based on development of decision trees using classification and regression applied to spatial data describing climatic conditions and distribution of kangaroos. The method presented in this paper has been implemented specifically as an inductive spatial modelling procedure operating within GIS and introduces a significant learning capacity to GIS function.

The dataset for analysis is habitat information and density of birds species for a moorland study area in north-east Scotland. The bird species of interest are Golden Plover (Pluvialis apricaria), Curlew (Numenius arquata) and Red Grouse (Lagopus lagopus scoticus). Habitat information is obtained from satellite imagery and topographic maps. All data are integrated within a Geographic Information System based on a combination of MicroVAX 3600 and PRIME 250 series minicomputers and a WYSE microcomputer; the systems are linked through DECNET. Image processing and some GIS functions are carried out using a GEMS Image Processing System (running on the PRIME) and ERDAS (on the WYSE); statistical and other modelling analyses are carried out on the MicroVAX using GENSTAT (Genstat 5 Committee 1987), MINITAB (Minitab 1988), and purpose written software. Graphical output is through UNIRAS and the GEMS.

STUDY AREA

The study area is located in Grampian Region and covers some 30 x 50 km of moorland, grassland, forestry and agricultural land (Figure 1). The area is part of the North-east Grampian Highlands which has a relatively dry climate, largely a result of a rain shadow effect from the higher Cairngorms to the west. Within the study area the mountains are higher to the west and lower in the east, summits typically being between 600 and 900 metres. Valley bottoms are at between 200 and 300 metres above sea level. Slopes are generally smooth but complex, rising steeply from valley floors to broad summits of gentle slope. The area was extensively glaciated during the Pleistocene, ice deriving from Rannoch Moor to the south and from more local

sources in the Cairngorms. The underlying geology is schists and granites although much of the area is covered by drift material, this being thicker in the valleys than on hillsides; soils are predominantly podsols and peaty podsols (Walker et al. 1982).

The relatively dry climate has restricted peat development and the moorland areas are dominated by dry and wet heath communities rather than blanket bog. The estates which own much of the area have traditionally managed the moors for Red Deer and Red Grouse. Management uses rotational burning of the heather to maintain a diverse age structure, and the area contains some of the most productive grouse moors in Scotland (Hudson 1988).

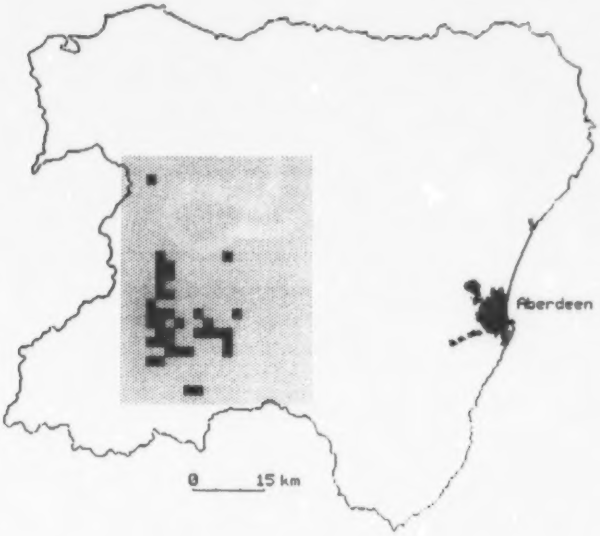

Figure 1 : Study area and Bird Survey sites in Grampian Region, North-east Scotland.

This management also benefits other moorland birds including Golden Eagle (Watson, Langslow and Rae 1987), Merlin and a variety of waders and passerines. The absence of deep peat and pool complexes restricts the distribution Dunlin (Calidris alpina but Golden Plover and Curlew, which tolerate drier, heathy conditions are widespread (Ratcliffe 1976). Passerines include Wheatear, Ring Ouzel, Meadow Pipit and Twite (Buckland, Bell and Picozzi 1990). Recent declines in grouse populations (Barnes 1987) combined with the high cost of labour intensive moorland mangement has resulted in expansion of coniferous afforestation on the moorland area, this reducing the area and fragmenting the remaining moorland habitat available to birds. Intensive agriculture is restricted to sheltered valley areas and pockets of more fertile soils.

DATA SETS : HABITAT INFORMATION AND BIRD SURVEY

Habitat Information

Bands 3, 4, and 5 of a LANDSAT 5 Thematic Mapper scene from 17 April 1987 are used as a source of habitat information. The image is geometrically corrected to the Ordnance Survey National Grid and pixels resampled to 25 metre resolution. The extract is cloud free but snow is present on the higher moorland areas. The aim of image classification is to characterise variation apparent in the grassland and moorland areas. This is achieved through a sequential combination of visual interpretation, masking, and a hierarchical classification procedure involving maximum likelihood and minimum distance algorithms (Veitch, 1989). The procedure is illustrated in Figure 2.

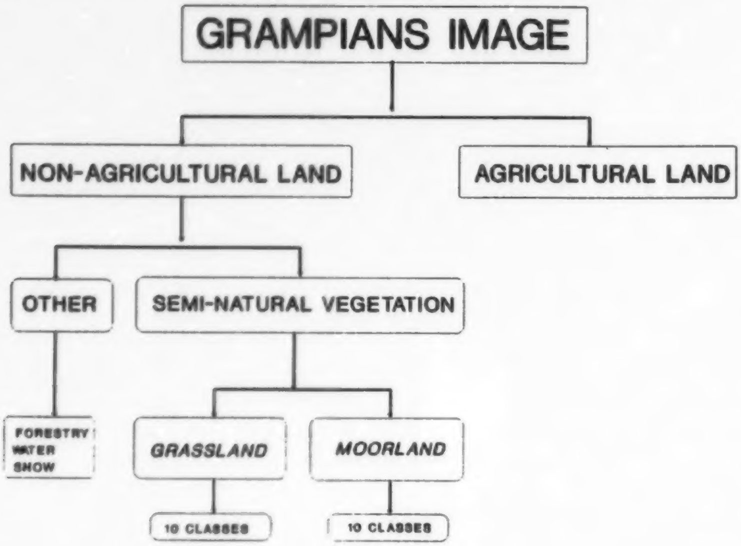

Figure 2 : Hierarchical Classification of LANDSAT Thematic Mapper Image of Moorland Study Area in Grampian Region

Initially, areas which are not of interest are removed; these are agricultural land, snow, forestry, and open water. Visual interpretation is used to produce a mask of agricultural land. This feature is clearly visible on the imagery and more readily and accurately separated using visual methods than spectral classification because context and texture can be incorporated into the classification. Agricultural land is then masked on the image and supervised maximum likelihood classification used to separate snow, forestry and open water. These three classes are used with the agricultural mask to create a separate mask image.

Both the image and mask are then smoothed with a 10 x 10 (250m x 250m) smoothing filter; this reduces spectral variation by removing high frequency image components. Smoothing the mask realigns the mask boundaries within the smoothed image and removes the effect of mixed pixels at the boundaries. A supervised maximum likelihood classification is then applied to identify general grassland and moorland classes. Before final image segmentation, the area of the image falling between the original mask boundaries and those produced by smoothing are allocated to the grassland and moorland classes. These pixels do not form part of the original mask, neither are they allocated to grassland or moorland on analysis of the smoothed image. The pixels are allocated to grassland and moorland using the GIS proximity function on ERDAS. These moorland and grassland classes are used in conjunction with the original image to produce separate grassland and moorland images. This procedure identifies moorland and grassland areas with high accuracy. Subsequently, each of the moorland and grassland images is separated into ten spectrally distinct classes using an unsupervised minimum distance to means classification algorithm

The spectral classes thus identified on the imagery are described using field data on vegetation recorded during bird survey carried out in the 1988 breeding season. Photographic prints of false colour composite imagery are used as a basis for field recording of vegetation (see Bignal, et al. 1988). Homogenous patches of colour on the imagery are matched with vegetation identified in the field and recorded on acetate overlay. Field vegetation data are recoded according to the plant communities of Scotland (Robertson 1984). The overlays are then coded into the ERDAS system, aligned with the imagery, and each spectral class described according to the plant community types which it intersects (Table 1). This provides no indication of classification accuracy after the accepted sense (Hay 1979; Story and Congalton 1986) although descriptions of the spectral classes allow some measure of ecological interpretation which assists development of models linking bird data to spectral classes.

Additional habitat data are derived from topographic maps and generated by use of the proximity functions of the ERDAS. Minimum and maximum height in each 1 kilimetre square of the National Grid is recorded from Ordnance Survey 1:50000 scale maps and maximum and minimum distance to agricultural land derived from proximity analysis of the inital mask of agricultural land.

Bird Data

Field survey provided data on both vegetation and bird numbers and was carried out between April and the end of June 1988. The number of Curlew, Golden Plover and Red Grouse found in 152 randomly selected 1 kilometre squares was recorded using standard Moorland Bird Survey methods (Shepherd et al. 1988). During 1989 a further 82 1 kilometre squares were surveyed. These data are used to test predictions made from the modelling procedure developed from data for the 1988 breeding season.

All data were compiled into a dataset using the 1 kilometre grid squares of the bird survey as the recording unit. Habitat information from the classified satellite image was summarised for each 1 kilometre square using the GIS to provide the proportion of each moorland and grassland class.

DATA ANALYSIS : INDUCTIVE SPATIAL MODELLING

The inductive spatial modelling procedure is based on application of Bayes' theorem; this approach has recently also been applied on a site specific basis as a method for wildlife habitat evaluation (Grubb 1988). The procedure has been integrated with the Geographic Information System described above to provide a flexible method for analysis of spatial distribution and also to improve the analytical functionality of GIS. Part of the appeal of the method is that it emulates the way in which a wildlife expert assesses habitat. The ability for a GIS to learn relationships between datasets has implications for integration of expert system shells with GIS. Inductive spatial modelling also has potential as a management tool; the effect of adjusting habitat characteristics can be investigated through analysis of consequent changes in probability and impact of a variety of management activity thereby modelled.

Distribution is predicted through a process which derives a probability of occurence. Bayes' theorem is applied to information on the frequencies with which specific attributes of habitat datasets occur in each of presence and absence categories of the wildlife distribution. The modelling process can be explained as a series of steps, each of which matches a procedure in its execution within the implementation in the GIS. Description of the programming procedure also highlights additional facilities not used in this analysis of moorland birds and their habitat.

1 Two classes are identified in a distribution to be modelled. These may be either i) presence and absence of a characteristic or ii) presence and a large random sample.

2 The frequency of presence and absence of attributes of habitat datasets are calculated for each of the two classes identified in 1. These frequencies form conditional probabilities for discriminating between presence (Po) and absence (Ao) of the distribution to be modelled. The frequencies are calculated against cutoff values for the habitat attributes, optimum values being found by iteration with the criterion of maximizing the statistical significance of difference between Po and Ao (see 3). An alternative approach maximizes the absolute difference between conditional probability scores (Po-Ao) (see Grubb 1988).

3 The significance of each habitat attribute for discriminating between classes is tested through analysis of frequencies using chi-square. The chi-square score can also be used in conjunction with the difference between the conditional probability for presence (Po) and absence (Ao) to decide which attributes should be included in the Bayes' model. Attributes which do not have a significant chi-square score are either excluded or allocated conditional probability equal to 1.0 for both presence and absence. Appropriate predictor datasets and attributes are then selected.

In the standard analysis characteristics of sites with known presence are compared with characteristics of sites with known absence to derive conditional probabilities. For wildlife distribution, and other geographic data, it is often the case that while presence is recorded, absence is not. This programme option allows the significance of conditional probabilities to be tested for the presence/random case (eg

Openshaw et al. 1987) and permits the model to be applied even if only presence is known.

4 Prior probabilities for each category of the model dataset are selected. These are estimates of the probabilities of presence (Pa below) and absence (Pc below) which are to be modified by the calculated conditional probabilities using Bayes' theorem. Two values are required, it being possible to set both to 0.5 if an initial assumption of equal probability for presence and absence is chosen. Other values may be selected; for example, prior probabilities may be set according to the proportion of all sites in which the species is present or in order to model a selected population size.

5 Conditional probabilities are combined using Bayes' theorem to provide a single probability value; this is the probability that the site will be occupied given the particular combination of habitat attributes at the site; it also provides a measure of the quality of the site for the species being considered. The equation for these calculations is :

$$Pp = \frac{A*C}{(A*C)+(B*D)}$$

where A = prior probability for presence
B = prior probability for absence
C = calculated by multiplying conditional probabilties for presence according to whether the habitat attribute is greater (Po) or less (1-Po) than the critical value
D = calculated by multiplying conditional probabilties for absence according to whether the habitat attribute is greater (Ao) or less (1-Ao) than the critical value
and Pp = probability of presence

RESULTS

Golden Plover were present in 91 1km squares sureveyed and absent in 61; the mean density was 1.9 (standard deviation 3.1). Curlew were present in 76 squares and absent in 76 with mean density 2.0 (standard deviation 2.9); Red Grouse were present in 142 1km squares and absent in only 10 (mean density 12.1, standard deviation 9.3). All species have highly skewed frequency distribution of densities with many more squares having low than high density.

The relationship between selected spectral classes identified by image classification and plant communities identified through field mapping is shown in Table 1. Spectral class Moorland 1 includes a wide variety of moorland plant communities dominated by Calluna. The composition of these communities is mixed and the variety in this spectral class is to be expected. Burnt areas are also included in this spectral class, this being partly a product of limitations on the field recording which failed to distinguish all burnt areas. Spectral class Moorland 5 also includes a variety of Calluna dominated moorland plant communities but also includes some grassland plant communities, notably Deer Grass Moor. Grassland plant

communities are associated with the Moorland 7 and 8 spectral classes. Moorland 6 contains small percentages of plant communities with a prostrate growth form including Mountain Azalea/Lichen Heath. The Grassland 1 spectral class represents Heath Rush/Fescue and White Bent/Tussock Grass types often found in association with Calluna (Robertson 1984). Spectral class Grassland 2 is associated with Vaccinium Heath, Grassland 3 with Heath Rush/Fescue and Soft Rush grassland types and spectral class Grassland 4 is grassland associated with blanket bog.

Table 1 : Selected Spectral Classes for Moorland and Grassland Images Compared with Plant Community Types (Robertson 1984)

Spectral Class	Moorland							Grassland			
Plant Community	1	5	6	7	8	9	10	1	2	3	4
Burnt Moorland	75	19				6					
Mountain Blanket Bog	67	8	2								
Mountain Azalea/Lichen Heath	66	28	2	2			5				
Boreal Heather Moor	60	32	2				2	3		3	
Bog Heather Moor	24	12		8			9	16		11	
Atlantic Heather Moor	17	4		6				11	5	5	13
Deer Grass Moor		80		20							
Vaccinium Heath	9	43	8	7					16	2	
Blanket Bog	23	38	7	9		2	2	3	1	2	12
White Bent/Tussock Grass	2	14		9	6			31	1	15	11
Bog Moss Water Track	6	29		31				7		6	2
Heath Rush/Fescue Grassland		4		11				35		27	16
Soft Rush Pasture				4				11		39	2
Conifers	20	6	24				14				

Values are percentages of the Plant Community associated with the spectral class

Conditional probabilities for presence (Po) and absence (Ao) for habitat attributes which have highly significant chi square scores ($p > 0.001$) for Curlew, Red Grouse and Golden Plover are shown in Table 2. Despite the variety of habitat (spectral) information available, relatively few classes are important; classes which are important are so for all three species. Different critical values are identified however. For example, the critical values for minimum altitude are 525m for Curlew, 575m for Red Grouse and 600m for Golden Plover (Table 3) This follows the pattern expected from knowledge of the ecology of each species (eg Ratcliffe 1976). Additionally, the conditional probability for presence is less than that for absence for 1 km squares with minimum altitude above the critical value for Curlew whereas the conditional probabilities for presence are greater than those for absence for both Golden Plover and Red Grouse.

These probabilities are used in Bayes' theorem to produce probabilities for presence (and absence) for each species across all kilometre squares in the study area. The relationships between predicted and recorded presence and absence are shown in Table 3 for all three species. The overall accuracy on development of the models is 80.3%, 88.2% and 53.9% for Curlew, Red Grouse

and Golden Plover respectively. Testing these models against bird survey data collected during the 1989 breeding season gives overall accuracies of 74.4% for Curlew and 57.3% for Golden Plover.

Table 2 : Conditional Probabilites for presence (Po) and absence (Ao) for Curlew, Red Grouse and Golden Plover

		Curlew		Red Grouse		Golden Plover	
Habitat Characteristics	Critical value	Po	Ao	Po	Ao	Po	Ao
Topographic Information							
Minimum Altitude	525m	0.30	0.84				
	575m			0.72	0.35		
	600m					0.91	0.25
Spectral Information							
Moorland Types (max 10)	3			0.96	0.75		
	6					0.36	0.87
Grassland Types (max 10)	5	0.57	0.12				
Total Moorland	20%					0.81	0.96
	21%			0.98	0.65		
	50%	0.83	0.99				
Total Grassland	1%	0.62	0.17				
	50%			0.05	0.35		
Moorland Class 1	10%			0.98	0.65		
	20%	0.76	0.92				
	43%					0.27	0.71
Moorland Class 6	2%	0.29	0.86				
	5%			0.67	0.25		
	10%					0.72	0.23
Moorland Class 7	1%					0.46	0.72
	4%	0.49	0.16				

(Chi square score significant ($p > 0.001$) for all probabilities shown)

DISCUSSION

The overall accuracies reported for the inductive spatial modelling are only an indication of 'success' in application of the method to habitat evaluation. In many instances it may be the misclassified sites which are of special interest in relation to both survey limitations and species ecology. For example, the species in this study are difficult to survey because their behaviour is inconspicuous (Ratcliffe 1977), they are highly mobile during their normal activity, and because the remote nature of the uplands makes multiple site visits difficult (Fuller, 1982). These combine to produce a situation where confidence in survey data is limited; specifically, for example, a record of absence in a survey unit does not mean that the habitat is unsuitable (Shepherd et al. 1988). The modelling procedure identifies a number of locations where habitat is assessed as suitable (predicted presence) but where no birds were recorded; similarly a number of locations are assessed as being unsuitable (predicted absence) although birds were

recorded as present during field survey. Clearly these differences between prediction and recorded information merit further attention in order to improve the modelling. The modelling also predicts presence and absence in areas outwith the bird survey area; this can assist with targetting field survey and contributes to wide area conservation evaluation.

Table 3 : Model Development - Predicting the Distribution of Curlew, Red Grouse and Golden Plover for the 1988 bird survey sites

1. Curlew

	Observations (1988 data)			
	Absent	Present	Row Total	Row %
Predicted				
Absent	58	12	70	82.8
Present	18	64	82	78.0
Total	76	76	152	
%	76.3	84.2		

Overall Accuracy : 80.3%

2. Red Grouse

	Observations (1988 data)			
	Absent	Present	Row Total	Row %
Predicted				
Absent	6	14	20	82.8
Present	4	128	134	78.0
Total	10	142	152	
%	60.0	90.1		

Overall Accuracy : 88.2%

3. Golden Plover

	Observations (1988 data)			
	Absent	Present	Row Total	Row %
Predicted				
Absent	34	43	77	44.2
Present	27	48	75	64.0
Total	61	91	152	
%	55.7	53.8		

Overall Accuracy : 53.9%

Inductive spatial modelling is one of a number of methods which can be used to identify suitability of a site on the basis of its habitat characteristics; it does however, have a number of specific advantages which recommend it as the preferred method for evaluation of wildlife habitat, particularly when operated within the context of a Geographic Information System. The advantages are related both to the process by which the probability model is developed and to the management tool which it provides. The advantages can be summarised :

a) inductive spatial modelling provides a search method whereby hypotheses relating spatial aspects of wildlife population (distribution) to habitat characteristics can be generated
b) the inputs to the model and the hypotheses generated are derived through automated analysis of relationships between habitat characteristics and wildlife data;
c) the method, as implemented, identifies threshold (critical) values where conditional probabilities for presence and absence associated with specific habitat characteristics can alter habitat quality. This offers potential for assessing management impact on habitat quality.

d) the approach incorporates a procedure for assessing statistical significance of relationships between datasets;
e) the combined use of Bayes Theorem and measures of statistical significance of model inputs allows a measure of uncertainty to be associated with the model output.

These advantages are supplemented by benefits which have more general application within Geographic Information Systems. The approach is relevant to a wide variety of spatial data and it allows models to be developed which make full use of available data. With increasing availability of spatial environmental and wildlife data in digital form and development of Geographic Information Systems and expert systems this method of modelling offers great potential.

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WILDLIFE HABITAT EVALUATION TOOLS: THE U.S. FOREST SERVICE'S FOREST INVENTORY AND ANALYSIS

Robert T. Brooks

Research Wildlife Biologist

USDA Forest Service, Northeastern Forest Experiment Station
Amherst, Massachusetts, USA

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SUMMARY

In response to legislative mandate, Forest Inventory and Analysis (FIA) research units of the USDA Forest Service's research organization have taken varied actions to implement a survey of forest wildlife habitat resources. The survey provides information at the state and regional level to local users and is aggregated nationally for the assessment of wildlife resources required by the legislation. The surveys differ in detail among FIA units but all are based on measurements of structural components and special features of forest wildlife habitat. The surveys have been reported in tabular format on single attributes of forest wildlife habitat and as estimates of habitat area of individual wildlife species. The two remaining tasks to satisfying the implementing legislation are: 1) agreeing on a minimum set of habitat attributes and and associated reporting standards for national Assessments, and 2) the validation of survey estimates as accurately measuring land-based attributes critical to wildlife resources.

Keywords: Wildlife habitat assessment, forest inventory

INTRODUCTION

The U.S. Department of Agriculture (USDA) Forest Service has been conducting extensive forest surveys since the 1930's. This work was initially mandated by the McSweeney-McNary Act of 1928 (45 Stat. 699), which called for a "comprehensive survey...of the present and prospective conditions of...the renewable resources of the forest and range lands of the United States ...and of the supplies of such renewable resources." The term "renewable resources" was not defined and in practice was limited to a commodity evaluation of forest area, numbers of trees, tree volumes, and growth by various classifications. The survey has been implemented regionally by research units located at seven Forest Experiment Stations in the Division of Forest Economics Research (USDA For. Serv. 1987).

In 1974, the McSweeney-McNary Act was amended by the Forest and Rangeland Renewable Resources Planning Act (RPA) (88 Stat. 476) that called for a "Renewable Resource Assessment...[that] shall include...an inventory, based on information developed by the Forest Service and other Federal agencies, of present and potential renewable resources..." Further, the RPA reaffirmed the requirement of the McSweeney-McNary Act for a survey of renewable forest resources, defined as "those matters within the scope of responsibilities and authorities of the Forest Service..."

A third Congressional Act, the Forest and Rangeland Renewable Resources Research Act of 1978 (92 Stat. 353), repealed the original McSweeney-McNary Act. The Act "complemented" the RPA by renewing the call for a comprehensive survey of renewable forest resources and by specifying renewable resources to include wildlife on forests and rangelands.

The first Assessment mandated by the RPA was produced in 1975, the second in 1979. A third is being produced in 1990. The forest resources included in the Assessment documents are outdoor recreation and wilderness, wildlife and fish, range, timber, lands and minerals, and water. At the time of the first Assessment, survey-based data were limited to timber resources. Each successive Assessment has identified the lack of data as a serious weakness in evaluating the supply of and demand for wildlife habitat resources on the nation's forests and rangelands (USDA For. Serv. 1975, 1979; Flather and Hoekstra 1989).

Responding to legislative mandates and information requests for the decadal Assessment, the Forest Inventory and Analysis (FIA) units at the Forest Service's Forest Experiment Stations have expanded their surveys to include forest wildlife habitat resources. This work, and that of the national Assessment in evaluating these resources are discussed in this paper, with emphasis on field and analytical techniques used by the various survey units to obtain proprietary data.

WILDLIFE-HABITAT SURVEY METHODS

Standards for the continuous forest survey mandated by federal legislation specify minimum information needs and levels of precision, and definitions and standards for certain measurements (Resource Inventory Handbook [FSH 1909.14], USDA For. Serv. 1989). Beyond these standards, individual FIA units are relatively autonomous with regards to survey design and implementation.

Traditionally, FIA has surveyed timberland resources. Timberland is that portion of forest land that is considered commercially productive and that is not administratively withdrawn from forest utilization. In 1987, timberland was estimated to constitute 66 percent of all forest land nationwide (Waddell et al. 1989). Eastern FIA units have surveyed both public and private forest land; western units with their vast acreages of public lands continue the difficult task of integrating information from separately administered public and private forest surveys.

Nationally, the FIA survey works to achieve a 10-year cycle within the conterminous states . The sample design is normally double-sampling for stratification, with aerial-photograph and field-sample phases (USDA For. Serv. 1987). Large numbers of aerial photo points are classified for stratification. The ground subsample of photo points ranges from one plot per 1200 hectares to one plot per 4000. The ground plot is typically a 10-point cluster of prism points, though fixed-radius plots also are used for sampling trees, regeneration, and other vegetation. From the plot, data are collected on plot-level attributes (e.g., geographic and physiographic location), stand conditions, and individual trees.

The assessment of wildlife habitat resources incorporates traditional FIA data and adds habitat-specific data variables (Labau 1984). In response to the RPA, the Southeastern FIA unit implemented multiresource forest survey procedures in 1977 during the fifth resurvey of South Carolina's forests (McClure et al. 1979). Resources considered in the survey include the land base, timber, wildlife, range, recreation, soils, water, fisheries, biomass, ecology, botany, diversity, protection, and use interactions (McClure 1979). Wildlife-related information in the survey was restricted to "measuring, classifiying, and evaluating [forest and rangeland] habitat." It was properly recognized at the beginning that the forest survey was unsuited for estimating animal abundance.

The habitat survey is based on the evaluation of "vegetative structure, plant species composition, and special features required by a given species of wildlife" (McClure et al. 1979). Specifically, the survey measured the vegetative structure, composition, and density in the overstory, midstory, and understory (Cost 1979); noted the presence or absence of [tree] cavities and snags, holes, caves, dens, brush piles, and hollow logs; and the presence or absence of water. The survey was judged best suited for evaluating "sensitive species" that require a special combination of forest habitat characteristics and that are sensitive to habitat disturbance, and for evaluating "adaptable species" that thrive in a diverse or mixed forest condition (McClure et al. 1979:22). The survey was considered less well suited for evaluating habitat conditions of transient (i.e., migratory) species, threatened and endangered species with restricted distributions, e.g., ivory-billed woodpecker (Campephilus principalis), and "recluse" species.

Habitat evaluation by the Southeastern FIA includes the use of screening models with plot-level survey data to assess species-specific habitat quality (McClure et al. 1979; Sheffield 1981). Each plot is ranked as unsuitable or as suitable (good, acceptable, or poor habitat) based on an evaluation of habitat attributes identified from the literature (Sheffield 1981). First a plot is rated based on minimum habitat standards for species occurrence. A plot determined to be suitable is classified into one of the three quality classes based on the sum of numerical scores for each habitat attribute. Once plots are classified by habitat quality, habitat-area estimates by habitat-quality class can be made using the area expansion factor for each plot.

The Northeastern FIA unit first implemented a forest wildlife habitat survey concurrent with the timber survey in 1978 (Barnes and Barnard 1979).

As with the Southeastern habitat survey, generic forest structure and special habitat features were quantified for use in developing tabular information and in assessing species-specific habitats. The Northeastern habitat survey also included a measurement of land-use edge from aerial photographs (Barnes and Barnard 1979; Brooks and Scott 1983; Brooks and Sykes 1984).

The Northeastern FIA also conducts a forest ownership survey that provides data on forest-land owners that are useful in assessing forest wildlife habitat (Brooks and Birch 1986, 1988). The survey consists of a questionnaire that is mailed to the owner of each forest FIA plot (Birch 1983). Information is obtained on the social and economic characteristics of owners, their reasons for owning forest land, and whether they intend to manage it for a variety of benefits, including wildlife, and the degree to which they have sought or have access to professional managment advice.

A third example of a multiresource forest survey is that implemented by the Alaska FIA (Larson 1984). Due to the large area and the remoteness of much of the state's forest, the Alaska FIA makes considerable use of remote sensing, including satellite imagery. Ground-plot measurements provide data on site classification, foliage structure, special features, signs of animal activity, and distance from the plot to other habitat resources.

The other four FIA units have incorporated measurements of foliage structure, standing-dead trees, and/or lesser woody-stemmed vegetation (Labau 1984; Hahn 1984; O'Brien 1984; Ohmann 1984). At the national level, the RPA Assessment integrates regional FIA data, public-lands survey data, and other land survey data (Flather and Hoekstra 1989). Habitat and wildlife evaluations are to be completed using, among other assessment tools, survey data-driven models (Hawkes et al. 1983; Flather et al 1989).

RESULTS/PRODUCTS

FIA units present survey data largely in tabular form in the Forest Service's Resource Bulletin series. More analytical reviews of surveys are presented in conference proceedings and peer-reviewed articles and tend to be issue-specific.

Prior to the efforts initiated in response to the RPA, the Southern and Southeastern FIA units had issued reports on deer browse and other forage resources, e.g., Ripley and McClure (1963), Sternitzke and Pearson (1974). Subsequent to the expanded survey efforts of the late 1970's, wildlife habitat information from FIA has become more diversified.

The most simple habitat surveys describe habitat attributes in tabular format. A forest wildlife habitat series was first published by the Northeastern FIA for the 1982 Maine forest survey (Brooks et al. 1986) and has been continued for every state in that region. For smaller states, wildlife information is combined with the timber report into a single publication, e.g., Dickson and McAfee (1988). Such publications report on landscape pattern, forest area, forest type and stand size, mast-producing,

standing-dead, and cavity trees, and lesser woody-stemmed vegetation. Early publications in this series contained a habitat assessment for the white-tailed deer (Odocoileus virginianus) as an example of an appropriate use of the data, e.g., Brooks et al. (1986). The assessment was based on an evaluation of land use and landscape pattern, forest area, and mast and browse potential.

The Southern FIA reports include nontimber resources as a whole in addition to wildlife habitat attributes such as nut-bearing, large-diameter, rotten, and standing-dead trees, e.g., Rudis (1984, 1988a). The Southern unit also produces survey-plot maps illustrating the distribution of habitat attributes, e.g., Rudis (1986, 1988b). Other FIA units have published survey statistics on various habitat elements in journal articles (McComb et al. 1986a, b), in symposia proceedings (Mead et al. 1987), and in state planning documents (FRRAP 1988; Ohmann et al. 1988).

The Southern and Southeastern FIA units have combined habitat attributes to estimate potential nesting habitat area of the red-cockaded woodpecker (Picoides borealis) (Lennartz et al. 1983; Rudis 1988b). Potential nesting habitat as used by Rudis (1988b) is estimated by stand-size, stand-age, and forest-type group. This is followed by an assumed minimum tolerance for hardwood stocking, and finally an assumed preference for particular pine species. Due to the uncertain validity of the criteria used, estimates of habitat area are reported for each of the more restrictive assumptions.

The use of screening models using enhanced FIA data to assess potential wildlife habitat was proposed by Sheffield (1981) following Lennartz and McClure's (1979) assessment of red-cockaded woodpecker habitat in the Southeast. He developed nine species habitat models based on plot data from the Southeastern FIA South Carolina survey, including vertical foliage structure. While the habitat models are unvalidated to date, the habitat-area estimates are described as "consistent with the qualitative descriptions of habitat and species abundance obtained from the literature" (Sheffield 1981:13).

Habitat models have been used by the Northeastern FIA unit to estimate potential breeding habitat for four species of woodpecker in West Virginia (Barnes and Barnard 1979). The Pacific Northwest FIA unit has used habitat models of the Forest Service's Wildlife and Fish Habitat Relationship (WFHR) program to estimate available wildlife habitats in California's hardwood forests (Nelson and Salwasser 1982; Ohmann and Mayer 1987).

It is the intent of the national Assessment of wildlife resources to use models of wildlife species' habitats to satisfy its legislative mandate (Hawkes et al. 1983). The national model-based process has been applied in the southern states (Flather and Hoekstra 1989; Flather et al. 1989). Inconsistent survey data sets among FIA units limit the application of habitat models for national assessments other than those of the most general design. An additional problem facing the national Assessment, as well as some of the regional forest inventory units, is the need to integrate disparate data sets from other public forest and rangeland surveys (Ohmann, in press; O'Brien, in press). In particular, the western inventory units must integrate data from the Forest Service's National Forest System as well as from other

agencies such as the U.S. Department of Interior's Bureau of Land Management and National Park Service, each with extensive land holdings.

DISCUSSION

Forest Inventory and Analysis has moved toward implementing a multiresource forest survey as required by the 1974 RPA and subsequent amending legislation. Because each FIA unit retains considerable independence in the survey process, progress in meeting the RPA requirements has varied regionally. The lack of a supportive constituency, both inside and outside the Forest Service, has done little to encourage research and application of truly multiresource forest surveys at the unit or national level.

Nevertheless, considerable progress has been made toward expanding the forest survey, particularly in the assessment of forest wildlife habitat resources. While there is no consensus as to the proper minimum data set for habitat assessment, most FIA units are collecting information on selected habitat attributes such as standing dead trees and understory woody-stemmed vegetation. Some units working cooperatively with the national Assessment team are synthesizing data elements in habitat assessment models. What remains to be accomplished are 1) an agreement among FIA units as to an acceptable minimum data set for habitat assessment, and 2) a validation that the FIA data and models assess forest wildlife habitat resources with acceptable accuracy and precision.

Without some degree of consistency in data collection, the FIA data will contribute little to the Assessment process. Hunt (in press) suggests that FIA collect--at a minimum--information on 1) nontimber vegetation, 2) dead and down material, 3) canopy conditions, 4) water resources, and 5) landscape characteristics.

Regardless of the type of data collected or the analytical processes used, unless there is validation that the data and results correspond to other measures of wildlife resources, the survey will fail to satisfy its objective. Whether the survey product is simply the status of single wildlife habitat attributes (e.g., standing-dead trees), or habitat-area estimates for wildlife species, there must be a proven relationship between these habitat esimates and measures of wildlife resources (Rice, in press).

One level of validation is proof that the FIA sample designs for estimating forest area and timber volume are adequate for estimating attributes of forest wildlife habitat quality. Hamel et al. (1986) found that Southeastern FIA regional estimates of structural vegetation habitat attributes adequately represent these same measures in a stand-level sample of older, upland oak-hickory forests. A second level of validation is consistent correspondence between FIA estimates of habitat attributes or habitat quality and measures of faunal rescurces. Estimates of potential habitat area for red-cockaded woodpeckers in the south have received preliminarily validation by visual correspondence between maps of potential habitat and known breeding colonies (Lennartz and McClure 1979).

A rigorous and complete validation of FIA efforts at forest wildlife habitat assessment is required to satisfy the legislative mandate for a survey of the nation's forest and rangeland renewable resources. More important, validation is necessary to assure the wildlife conservation community that the FIA wildlife habitat survey is a useful and important product deserving of its support.

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A REVIEW OF SOME WILDLIFE HABITAT INVENTORY AND EVALUATION PROGRAMS APPLIED IN CANADA

Paul A. Gray[1] and Duncan Cameron

Ph.D. Candidate and Associate Professor
Biology Department

York University
4700 Keele St., North York
Ontario, Canada, M3J 1P3

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SUMMARY

Forests cover approximately 4.5 million km² of Canada, and provide significant social, economic, and environmental benefit. In the last 20 years, increasing land use pressures have precipitated the creation of legal, administrative, and technical programs to manage complex and often competing land uses. Wildlife resources constitute an important and valued use of forest lands. This paper summarizes some of the wildlife habitat inventory and evaluation programs developed or adopted in Canada to provide a technical basis for incorporating wildlife values into land use decisions.

Keywords: Wildlife, habitat, evaluation, surveys, techniques

INTRODUCTION

Canada is a vast (approximately 10 million km²) and diverse country in which forests cover almost 4.5 million km² (Bird and Rapport 1986:113). Approximately 2.6 million km² are classified as commercial forestland, 80% of which are publicly owned (Lang and Armour 1980:91). Almost 160,000,000 m³ of timber are harvested annually, contributing to nearly 20% of the total value of Canadian exports in 1980 (Bird and Rapport 1986:245). But forests do many other things in addition to providing a significant economic base for the country. They control run-off, contribute to the

maintenance of water supplies, control microclimate, contribute to the CO_2/O_2 balance of the world's atmosphere, provide habitat for wildlife, and provide recreation, education, and research opportunities (Lang and Armour 1981:91).

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[1] Present Address: Wildlife Branch, Ontario Ministry of Natural Resources, Queen's Park, Toronto, Ontario, Canada, M7A 1W3

Canadian forests, ranging in size from a few m^2 to thousands of km^2, provide habitat for a significant portion of Canada's wildlife species. But in these times of increasing human population, increasing urbanization, resource extraction, industrialization, and increased pollution levels, it is growing more difficult to effectively manage our forest and wildlife resources. In response, wildlife managers are working to develop and implement useful techniques to collect, analyze, and report on wildlife resources within numerous land use planning and assessment programs across the country.

A GEOGRAPHICAL CONTEXT FOR WILDLIFE HABITAT EVALUATION

Resource managers constantly face a bewildering array of land use issues. Resolution of these issues often involves the use and manipulation of large data sets collected at various mapping scales and during different periods of time. Considerable time and money have been spent developing a consistent approach to land use (including wildlife) management through ecological land classification (ELC) programs, which can provide a "shell" in which to employ large data bases at various scales.

ELC is founded on the principle that land can be classified into ecologically significant geographical units based on recurring patterns of climate, soil, landform, and vegetation (Kansas 1986:1, Wiken 1986:2). This holistic and hierarchical approach to land classification is applied on the basis of scale ranging from very site-specific (eg., 1:2,500) to very broad ecosystems (eg., 1:1,000,000). In essence, ELC represents an interdisciplinary approach to gathering and interpreting environmental data which can be used to address a wide range of issues. While there is no consistent application of ELC at the various scales across the country, numerous, often complementary, studies have been completed (see Wiken 1986) by various jurisdictions.

WILDLIFE HABITAT EVALUATION PROGRAMS

Animal habitat is the temporal and spatial arrangement of environmental attributes required to meet the biological needs of a species, whereby each species is adapted to a specific arrangement and amount of food, cover, and water (Thomas 1979:15). Traditionally, wildlife research and management programs were focused on the collection and analysis of species abundance data (Eccles and Stelfox 1985). This is likely because early efforts to identify, catalogue, and interpret wildlife habitat were hampered by poor survey techniques, difficult terrain, the lack of relatively inexpensive inventory techniques, and the absence of efficient data storage, management, and retrieval systems (Mayer 1984). But population survey results are prone to biases and inaccuracies (Caughley 1974). In recent years there has been a dramatic shift away from population studies in response to the need for more cost effective data collection methods, and more defensible methods to represent the data in the decision-making process (Eccles and Stelfox 1985, Eccles et al. 1988:23, Green et al. 1986). New and refined survey techniques (eg., remote sensing), user-friendly computer systems, and increased understanding of ecosystem dynamics have fostered significant advancement in the utility of a habitat-based approach to management.

In the case of broad scale ecological mapping (1:250,000 to 1:1,000,000) suitable habitat variables can include vegetation form, soil, relief, regional precipitation, and geological parent material (Demarchi and Lea 1989, Eccles et al. 1988:23, Eng and Stelfox 1985). More detailed studies are required for localized assessment of wildlife habitat because the wildlife-supporting capabilities of site-specific cover types (rather than large ecological units) need to be determined (Eccles et al. 1988:23). Localized assessments are more detailed and may be based on forest

canopy composition, forest canopy closure, and browse densities (Cooperrider 1986:xvii, Eccles et al. 1988:23).

Canada Land Inventory (CLI)

The CLI was the first attempt to classify comprehensively the capability of land to support agriculture, recreation, forestry, and wildlife (ungulates, waterfowl, and sport fish) in Canada (Demarchi and Chamberlain 1978, Wiken and Ironside 1977). The study area covered 1,609,000 km^2 including all of the Atlantic provinces, settled portions of Ontario, Quebec, and the western provinces (Demarchi and Chamberlain 1978). For wildlife, data were collected through reconnaissance level aerial surveys, ground surveys (eg., browse survey and pellet group counts), interviews with knowledgeable people, and literature reviews. Land capability ratings for wildlife were assigned on the basis of ecological conditions expected to prevail if the lands were managed for wildlife. Capability classification for wildlife is based on 7 categories (very good to very poor), and the inventory data are published as maps at a scale of 1:250,000.

The CLI provides useful information about the capability of a land unit to provide optimal wildlife habitat at some point in time. It is extensive in scope, and provides a useful overview and an organized data base from which more detailed, stratified surveys can be planned (Stelfox and Ironside 1982, Stelfox 1985, Wildlife Habitat Canada 1986:38). Jakimchuk (1982) felt the CLI to be useful because it provided a more objective assessment of habitat importance than could be reflected in single point-in-time population estimates, which tend fluctuate from year to year.

The CLI has been criticised because it is a single-use capability system (not integrated), does not describe land ownership, is limited to ungulates and waterfowl, does not reflect other factors which constitute habitat, and lacks detail and quantified data (Demarchi and Chamberlain 1978, Jakimchuk 1982, Stelfox and Ironside 1982, Wildlife Habitat Canada 1986:38).

B. C. Biophysical Inventory (BCBI)

The province of British Columbia initiated the BCBI program in the mid-1970's after the completion of the CLI program (Demarchi and Chamberlain 1978). The goal of the program is to provide a hierarchical classification framework to assess the suitability (existing habitat conditions) and capability (potential) of land for supporting wildlife populations and for improving wildlife habitat. The classification system is based on the synthesis of physical and biological attribute data (Demarchi 1985, Demarchi and Lea 1989). It is conducted within a hierarchical ecological land classification framework (Demarchi and Lea 1989).

After the biophysical base maps are prepared by a resource management team comprising a pedologist, a vegetation ecologist, and a wildlife biologist, the ability of each land unit to support wildlife is assessed (Demarchi and Chamberlain 1978). The evaluation of biophysical data is supplemented with aerial survey results, pellet group counts, browse surveys, and discussions with knowledgeable people (Demarchi et al. 1981, Jakimchuk 1982). The ability of a unit to support wildlife is expressed as one of 6 classes (very high to no capability) (Demarchi 1982). The maps are developed at various scales; scales of 1:50,000 and 1:20,000 are the most common (Demarchi and Lea 1989). Fuhr and Pendergast (1983) employed this technique to complete a moose habitat assessment in west-central British Columbia.

This map series is an improvement over CLI because it is integrated, providing information about recreation, terrain, soils, vegetation, stream properties, and wildlife habitat (Stelfox and

Ironside 1982). The hierarchically organized biophysical descriptions allow the user to develop capability classifications for any wildlife species at a variety of map scales (Demarchi and Chamberlain 1978).

Northern Land Use Information Series (NLUIS)

The NLUIS is a reconnaissance level survey program initiated in 1971 and designed to provide broad, consistent coverage of the Yukon Territory and the Northwest Territories (Ironside et al. 1982). Biological (including wildlife), physical, cultural, and economic characteristics are mapped at a scale of 1:250,000 (Ironside et al. 1982). Preliminary wildlife habitat boundaries are delineated and described during pre-field study (literature review, examination of Landsat images, and discussions with knowledgeable people). The field program involves reconnaissance flights and ground checks of selected sites. All pre-field and field data are integrated during post-field analyses and description (Ironside et al. 1982), at which time the final boundaries are drawn.

This technique allows resource managers to delineate critical wildlife habitat, identify seasonal movements, and distinguish between habitat functions (eg., breeding, wintering and calving sites) (Jakimchuk 1982). With some exceptions, the product is a series of broad-based maps for the entire north. Critics suggest that the product is simply a series of topographic maps with some generalized wildlife information added to it and that there is no indication of survey locations (ie., flight lines) (Stelfox and Ironside 1982). During the early years of this program this was true, but it evolved into an ELC-based program in the 1980's.

Terrestrial Wildlife Habitat Inventory (TWHI)

The TWHI was initiated in 1975 for agricultural Saskatchewan in response to increased pressure on remaining wildlife habitat by agriculture (Flory and Schmidt 1982, Hart et al. 1979, Stelfox 1980). Topographical data (ie. land system), land ownership, land use, and critical wildlife habitat data were collected and mapped at a scale of 1:250,000. Upland game birds, ungulates, and rare and endangered species were the primary wildlife features considered (Flory and Schmidt 1982). A team of three ecologists placed heavy reliance on existing data, but some field assessments were completed (Stelfox 1980).

The program promotes good public relations, provides a consistent base map for additional thematic classifications, provides a common meeting ground upon which resource specialists can more effectively communicate their needs and concerns, and provides a product with which to set priorities for addressing land use issues (Hart et al. 1979, Stelfox 1980). The program is limited because there is no detailed ranking of habitat, marginal habitats (which may be relatively important) are ignored on the maps, vegetation data are not included on the maps (but are described in tables), it relies heavily on existing information, it is difficult to update, and the data are too general for detailed assessments (Flory and Schmidt, 1982, Hart et al., 1979, Stelfox, 1980). These problems are addressed, in part, through the current provincial program whereby field biologists familiar with the area complete on-site re-evaluations (Arneson pers comm.). In addition, Saskatchewan is currently planning to introduce the Habitat Evaluation Procedures (HEP) developed by the U.S. Fish and Wildlife Service (1980), which will employ TWHI data (Arneson pers comm.).

Alberta Wildlife Modelling Program

The Alberta government sponsored development of an ecological land classification map (1:1,000,000) which identifies 12 major climatic zones as represented by general vegetation patterns or wildlife habitat regions and 278 subregions on the basis of major physiographic and geomorphic landform features (Eccles and Stelfox 1985, Eng and Stelfox 1985). The map describes vegetation cover, land surface disturbance, landforms, aquatic forms, soils, moisture regimes, and winter severity for each region. The purpose of the program is to assess current habitat suitability (CHS) for selected wildlife species using numerical rating schemes (models) in which the important habitat variables are identified and rated (Eng and Stelfox 1985, Green et al. 1986).

Within the ELC framework, resource specialists develop and apply the species-specific index of current habitat suitability (HSI) (Eccles and Stelfox 1985). The model is described in detail by Eccles and Stelfox (1985), Eccles et al. (1988:24), Eng and Stelfox (1985), Green et al. (1986), and Rayner and Bennett (1985). It is constructed in four steps. In the first step the important life requisites for the species in question (eg., food and cover) are identified. The second and third steps require that the modeller weight and rank habitat variables according to their importance to the species in question. In Alberta the current habitat suitability index (CHSI) is calculated using a four-class (0-3) scale (inadequate=0 and best=3). Fourth, the numerical rating scheme is applied using additive or multiplicative models.

This model is fashioned after the HEP's (see USFWS 1980). In Alberta this modelling technique has been used for a number of large mammals at broad and site-specific mapping scales (Eccles and Stelfox 1985, Eccles et al. 1986).

Model output is then mapped according to the scale of the data used in the model. The advantages of this approach include the fact that the model is applied within a hierarchical framework, the model is highly adaptable and user-friendly, is repeatable, and each assumption is well documented (Eng and Stelfox 1985). The broad scale or regional models facilitate declaration of provincial and national status of wildlife, permit managers to identify provincial wildlife management planning priorities and rationalization of budgets, input to strategic planning, and to identify present and future wildlife supply and demand trends (Eccles and Stelfox 1985). At the site-specific level, the models are used to determine CHSI's for local populations and to address specific questions (eg., timber cutting management plans).

As with all assessments, the models are limited by virtue of the fact that their predictive ability depends on the quality of the biological data used in their development (Eccles and Stelfox 1985). Other factors such as wildlife behaviour patterns and human-induced disturbance can influence the distribution and abundance of wildlife, but not be reflected in the models (Eccles and Stelfox 1985).

New Brunswick Habitat Supply Analysis Model

The New Brunswick government and its partner, Wildlife Habitat Canada, initiated a forest-wildlife habitat project in 1985 to foster development of a system to integrate wildlife habitat management concerns with forest management planning (Patch 1987, Sullivan 1989). Habitat supply analysis (HSA) is a bookkeeping process used by resource managers to predict the future availability of wildlife habitat (vegetation) (Patch 1987). The model employs wood supply analysis techniques to forecast the availability of stands that provide habitat for selected wildlife species. The procedure requires that managers define the response of wildlife populations to forest stand

availability. The model is similar to the HEP models, and comprises a series of tables and graphs or equations which express the suitability of forest stands for a wildlife species.

The technique presently is being tested on an 83 km^2 area where field staff assess the ability of a forest stand to provide habitat (eg., summer food and winter cover) on the basis of vegetative structure. A wood supply model is employed to monitor forest class availability through time to generate temporally meaningful results for input to forest cutting plans (Patch 1987). Program development is ongoing. Products include a preliminary set of habitat relationships for 15 wildlife species, a computerized data base, habitat validation procedures, and confirmation of habitat supply forecasting techniques. Like other programs (eg., Alberta), this program eliminates wildlife as a significant management constraint, and provides managers with the necessary tools to meet feasible land use (forest) management objectives (Patch 1987).

Additional Examples

Many habitat evaluation studies are completed in response to specific management questions each year across the country, and although many of them are not completed within the context of a large program like those outlined above, they are important management tools. For example, in 1986 the Government of Newfoundland and Labrador implemented an experimental project to assess the feasibility of using Landsat Thematic Mapper data to classify and inventory moose habitat at a scale of 1:50,000 (Oosenburg et al. 1988). Bowles (1985) reported on a study in Manitoba to stratify moose habitat using unsupervised classification of Landsat data to reduce aerial population survey costs. Dixon et al. (1982) examined the feasibility of using Landsat imagery to maintain ongoing monitoring of white-tailed deer (Odocoileus virginiana) habitat in southwestern Manitoba, and Polson (1985) employed Landsat imagery to map vegetation in Saskatchewan in support of wildlife studies. In Ontario Thompson et al. (1981) employed aerial photographs in combination with aerial population inventory data to describe moose habitat at a scale of 1:15,840. Guertin et al. (1984) described moose winter habitat in Quebec by employing similar techniques.

CONCLUSION

The programs described above are implemented through the use of a variety of data collection techniques including remote sensing (eg., low-level aerial photographs and Landsat images), aerial surveys (eg., reconnaissance and stratified transect or block surveys), population ground surveys (pellet counts, winter track counts, roadside surveys, browse surveys, live trapping, bio-telemetry, den counts, scat analysis, nest surveys, etc). Similarly, treatment and analyses of the data vary according to the questions being asked, the type of resource experts involved (eg., inventory vs. modelling specialists), and available funding and time.

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EVALUATION OF GREY KANGAROO HABITAT IN QUEENSLAND, AUSTRALIA

Greg J.E. Hill

Reader in Geography
Department of Geographical Sciences

The University of Queensland
St Lucia, Brisbane, Australia

FDC: 156.2: 149.2: 585: (943)

SUMMARY

The eastern grey kangaroo is the most common and widely distributed of the kangaroo species found in Queensland. It is particularly abundant across the vast inland rural zone where it is commercially harvested as a pest species. Monitoring of kangaroo habitat across the rural sectors of the state poses special problems. While map and aerial photo coverage exist, factors such as scale and cost (for photography) and level of detail (for maps) are severe drawbacks. Recency of data capture is often a severe drawback for both products. Satellite imagery, on the other hand, overcomes most of these problems. Landsat MSS data, for example, are well suited to kangaroo research at the regional level of detail. Reliable habitat maps can be produced from the digital data and photographic products are particularly useful for planning and conducting aerial surveys that monitor kangaroo density and distribution.

Keywords: grey kangaroo, remote sensing, habitat, management, Landsat, aerial survey

INTRODUCTION

The eastern grey kangaroo (*Macropus giganteus*) is the most widespread and abundant of the large kangaroos found in Queensland. Although they have evolved for life in a woodland-type habitat and are rarely found far from shelter (e.g. Frith and Calaby 1969) grey kangaroos exist in high densities in widely separated and dissimilar ecotypes (Figure 1). The most preferred habitats provide a balance between food reserves and cover (Hill 1981). As climax forest and woodland are typically lacking in suitable ground forage it is the edges, where these habitats abut cleared country and to a lesser extent crops, that are particularly attractive to grey kangaroos. Logged and regrowth areas also support high densities because of the dual availability of food and shelter. Grey kangaroos have been one of the few species of native fauna to benefit from the European settlement of Australia. Densities now are certainly much higher than at the time of settlement (e.g. Lavery 1985).

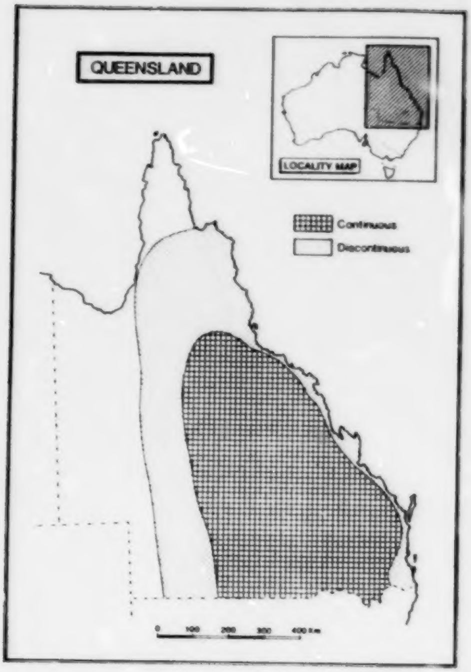


Figure 1: Distribution of the grey kangaroo in Queensland (from: Kirkpatrick 1974)

This positive relationship between grey kangaroos and humans is most marked in the pastoral zone and marginal cropping lands of inland Queensland. Here provision of improved forage reserves has been supplemented by permanent water. It is in these areas that grey kangaroos are often regarded as pests by landholders. They have been commercially harvested in Queensland for well over a century. Annual harvests have varied between approximately 400,000 and 900,000 over the past decade with the range in size of harvest largely due to climatic variations which govern shooter access. Larger harvests are taken in drier years. Harvesting is controlled by a quota system enforced by the Federal Government which bases its harvest totals on kangaroo population estimates, derived from aerial survey, and advice from the State Government.

Because of the huge areas over which kangaroos are commercially harvested and/or destroyed as pests, management needs to be conducted at the regional level. This is one reason aerial survey is widely used to monitor kangaroo populations in Australia. However, at this regional level, mapping and monitoring the habitats upon which kangaroos rely pose

problems for the wildlife ecologist/manager. The aim of the present paper is to outline the options available for habitat evaluation at the regional scale. Particular emphasis is given to deriving habitat information for use in kangaroo, aerial survey programmes.

THE GREY KANGAROO

Fully grown eastern grey kangaroos are impressive animals (Figure 2). Males may weigh as much as 90 kg (200 lb) with females attaining a little less than half this weight. Colour ranges from pale sandy greys through brownish greys to dark bluish greys. Grey kangaroos may breed throughout the year although a well defined summer maximum exists. Females mature between 17 and 28 months of age while males rarely mate before their fourth year (Kirkpatrick 1965). The gestation period is 37 days and as the joey normally remains in the pouch for around 300 days, females are capable of producing only one young per year. On vacating the pouch joeys continue to suckle for at least another six months before being completely weaned.

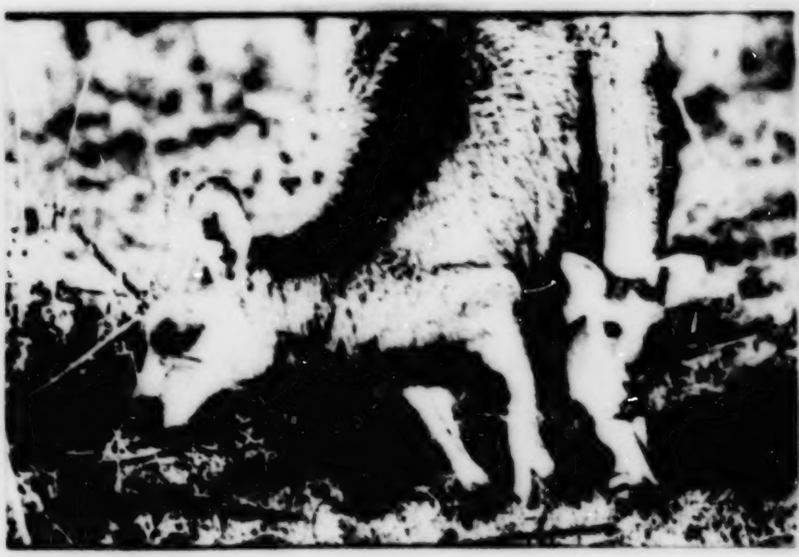


Figure 2: Female eastern grey kangaroo with a well developed joey in the pouch (photo by Qld. NPWS)

As noted previously, grey kangaroos have wide ecological tolerances and occupy a large proportion of Queensland. Habitats include sclerophyll

forest, savanna woodlands, dense inland scrubs, coastal heaths and semi-cleared and cleared pasture lands. In the arid western areas they are restricted to watercourses and sources of permanent water. In coastal

regions they tend to avoid closed forest and areas of rugged terrain. Grey kangaroos are primarily graziers and rely heavily on grasses (Kirkpatrick 1965, Griffiths and Barker 1966).

CONVENTIONAL SOURCES OF HABITAT INFORMATION

The traditional base for aerial survey of kangaroos is the topographic map at a scale of 1/250,000 (e.g. Caughley et al 1977). This forms a convenient unit for selecting and navigating flight paths. Generalised habitat information is provided by these sheets but in the inland areas where kangaroo census work is conducted no more than three or four land cover categories would normally be available. For example, for the Goondiwindi region, where the present author conducts survey work, the topo maps record the classes: forest or scrub; scattered vegetation (; and no woody vegetation). These data may be useful in defining gross habitat patterns and dividing survey areas into visibility strata for correcting observed counts of kangaroos (e.g. Caughley et al 1976). However, these tasks must be undertaken with caution because of the outdated nature of much of Australia's medium scale, topographic mapping of rural areas. Most of the 1/250,000 coverage of Queensland, for example, is based on 1960s aerial photography. Over much of the grey kangaroo's range, pastoral and agricultural development since this time have changed the face of the land markedly.

Another map source of habitat information is the land systems maps available for much of rural Australia. Developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), this landscape approach classifies the land, particularly at the reconnaissance level, by identifying mapping units which exhibit similar geomorphic features, soils and vegetation (Christian 1958, Christian and Stewart 1968). The resulting maps attempt to define the natural landscape of regions. In other words, they depict the environment prior to European settlement. Vegetation maps derived from land system reports therefore depict climax vegetation and do not give an indication of current vegetation patterns. So, while the level of detail available on vegetation communities and associations, and cover types may be high, it is often of little use to the wildlife manager. The scale of mapping is usually 1/500,000 or smaller which further limits the usefulness of these products for kangaroo research.

Oblique aerial photography is often taken during kangaroo survey flights to record kangaroos and habitat. These photographs form a useful reference of animal/habitat associations and may be keyed to map sheets and flight records to assist in compiling or updating vegetation maps of survey areas. For comprehensive habitat mapping, however, complete stereo coverage of vertical photography is required. Such coverage at scales of 1/25,000 or 1/40,000 is available for all of Queensland. However, for rural areas the photography may be 20 years or more old. Uncontrolled mosaics and rectified mosaics at a scale of 1/100,000 have been compiled for limited

areas of Queensland. These are ideally suited to assessing regional habitat patterns but all available mosaics are compiled from 1960s photography. The greatest use, therefore, is as a habitat record at a point in time between the climax vegetation map (land systems surveys) and the present land cover situation. Given the constraints noted and the cost involved in obtaining photo coverage for large areas conventional aerial photography is better suited to local area studies than population monitoring at the regional level.

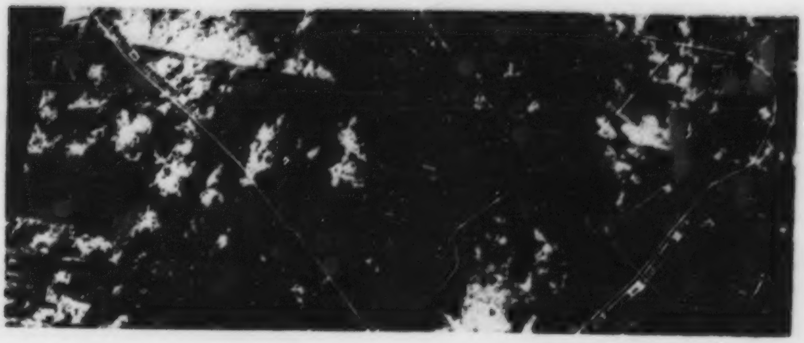
SATELLITE IMAGERY FOR HABITAT ASSESSMENT

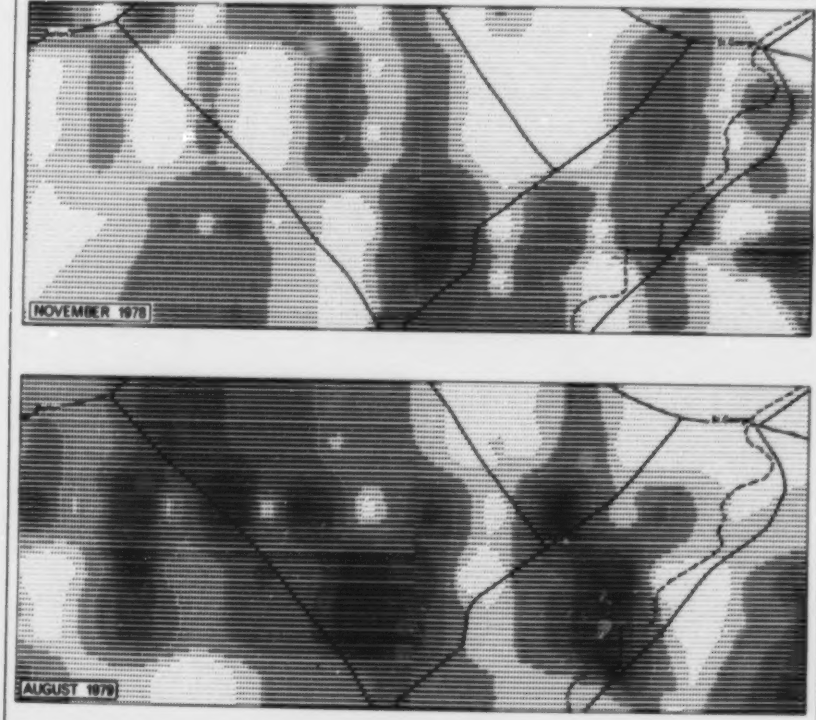
The utility of Landsat MSS data for regional habitat inventory in kangaroo management was recognised in Australia soon after the launch of the first satellite in the Landsat series. Fox (1974) used a Band 7, black and white mosaic for the state of New South Wales to define kangaroo habitat zones. He found that the imagery was valuable in identifying areas of land under monoculture and the distribution of remaining belts of scrub/timber. Despite this encouraging, though albeit low-key, trial of the new data and periodic review papers defining its potential (e.g. Falconer 1979) limited use has been made of Landsat in wildlife applications in Australia since this time.

It was in the 1970s that controversy over kangaroo conservation, both in Australia and overseas, led to the adoption of aerial survey as a key component in management of the large, commercially exploited kangaroos. With emphasis on population totals and the refinement of survey design and methodology, the habitat component of the management equation was thought, by some, to be neglected (e.g. Jarman 1979). Satellite imagery is, however, well suited to supporting many facets of aerial survey programmes as well as supplying the habitat information necessary for a comprehensive assessment of kangaroo conservation and management.

In a similar way to Fox's (1974) early use of satellite imagery, Landsat colour composites or single band prints may be used to divide large regions into habitat zones for aerial survey work (Hill 1982). The low cost of small scale, photographic products and the ease with which they can be compiled into mosaics favours this approach (Figure 3). Within local regions, large scale imagery at 1/250,000 or 1/100,000 is well suited to manually mapping major land cover and land use patterns. As illustrated by Hill et al (1988) this approach facilitates the selection of study sites suited to specific research goals and aids in the interpretation of results obtained from aerial survey and ground based assessments of kangaroo density and distribution.

Figure 3 (following page): Changes in grey kangaroo density and distribution (aerial survey data) between November 1978 and August 1979 in the Bollon - St George area of southern, inland Queensland. Drought conditions (1979) and easier sighting of animals in winter (August) explain the enormous, observed density difference. The Landsat Band 5 mosaic facilitates interpretation of distribution patterns.





GREY KANGAROO DENSITY
SOUTHERN QUEENSLAND

In addition to interpretation of photographic products, Landsat data may also be analysed using computer based image processing systems to provide more detailed and reliable habitat classifications. Hill and Kelly (1987) demonstrated that digital processing of MSS data was able to replicate the standard habitat categories recorded during aerial surveys of kangaroos on the fringe of the wheat belt in southern, inland Queensland (Hill et al 1985, 1988). Despite the inherent advantages of the digital approach to image interpretation the higher costs involved may mitigate against the routine adoption of digital data as the habitat base for broadscale, kangaroo survey operations of the type currently conducted in Australia. For more intensive aerial survey work, however, the speed, reliability and finer detail obtained from digital processing make it an ideal base for assessing animal/habitat relationships (e.g. Hill and Kelly 1987) or conducting research into aerial survey bias (e.g. Barnes et al 1986).

One extremely practical use for Landsat imagery is as a navigational aid during survey work. Topographic maps at a scale of 1/250,000 are the standard navigational base for aerial survey of kangaroos. However, at a survey altitude of 76 metres the rather sparse set of reference features plotted on these maps (for rural areas) is often not readily visible from the aircraft. Furthermore, the land cover and cadastral information recorded on topo maps is often hopelessly out of date and may confuse the navigator and/or survey team. While the sophisticated navigation systems now available on survey planes have eased the major problems related to locating specific points and following predetermined flight paths, reliable, readily interpreted maps are still required for wildlife survey work from aircraft. Landsat MSS colour composites at scales of 1/250,000 and 1/100,000 have proved ideally suited to the task in the research programme reported here. There is a comparative wealth of navigational cues available from Landsat. In addition, the clear differentiation between land cover types and individual paddocks makes it possible to plot the positions of groups of kangaroos on the imagery where distributional data are required at this level.

CONCLUSION

The role of habitat in determining wildlife density and distribution is well documented. However, given the scale of the eastern grey kangaroo's range in Queensland, reliance on conventional aerial photography for comprehensive habitat mapping is not practicable. Likewise, existing vegetation maps such as topographic sheets or those derived from land systems studies are usually of limited value. Little attention has been paid to mapping current land cover and land use in Australia.

This situation can be remedied through the use of Landsat MSS imagery which has resolution parameters well suited to the regional scale at which kangaroo management programmes need to operate. The imagery is also a useful map base for planning and conducting the aerial surveys that are used to monitor kangaroo density and distribution. While these conclusions

may appear self-evident given the long established credentials of Landsat in wildlife habitat mapping, little use has been made of the data source in Australia for wildlife applications in general or kangaroo research in particular. This is despite growing awareness and use of remote sensing in closely related fields of study such as forestry, land use and general vegetation mapping.

The work reported here neglects sensor systems other than Landsat MSS. This is because the imagery is the most appropriate and cost effective data source for use with the aerial survey programmes currently relied upon to direct kangaroo management. Other satellite systems, however, offer the opportunity to attain additional research goals. NOAA AVHRR data for example, are being used with success in Queensland for drought monitoring (e.g. Dudgeon and Jones 1987). Drought maintains an overriding influence on the natural mortality of grey kangaroos and plays a major role in determining the success rate of commercial shooters. Access to regular information on pasture status across the state is a potentially powerful tool for wildlife managers wishing to monitor seasonal conditions and their impact on kangaroo populations. The high resolution data from the new generation, satellite sensors, such as Landsat TM and SPOT, also have obvious application in kangaroo research. The challenge for wildlife managers, however, is not so much adopting this newer technology but rather taking advantage of the information that has been available from Landsat MSS since 1972.

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VEGETATION, STRUCTURE, HUMANS,AND SURROUNDINGS AS FACTORS IN STRUCTURAL LOSS FROM WILDLAND FIRES

Robert E. Martin

Professor
University of California
Berleley, California, United States of America

FDC: 431.2: 432.2/.3

SUMMARY

Vegetation cannot be separated entirely from other aspects of the urban/wildland fire problem. A structure could be designed and constructed to withstand almost any wildland fire problem. In contrast, a very poorly designed structure might easily fall victim to a fire in very light fuels some distance from the structure. In addition, the presence of humans at the sight during a fire can be the deciding factor between survival and loss.

Keywords: Fire, structure, vegetation, human

INTRODUCTION

There are many ways we can express the various factors contributing to the survival or loss of a structure during a fire in nearby vegetation. Here, I have used the term vegetation, not wildland fuels, because some of the vegetative fuels are often from planted species

Probability of survival (P_s) of structures during vegetative fires can be expressed in equation form. My form is as follows:

$$S_p = f(V_q, V_c, V_{ch}, V_{mc}, V_s, V_b,)(S_m, S_s, S_1, S_p)(L_a, L_{loc}, L_{lay})(H_a, H_t, H_e)$$

where,

S_p = survival probability

V_{ch} = vegetation chemistry

V_{mc} = vegetation moisture content

V_s = vegetation particle size, shape, and density

V_b = vegetation packing ratios
V_c = vegetation continuity
V_q = vegetation quantity
S_m = structure materials
S_s = structure shape
S_l = structure location
S_p = structure protection devices
L_a = locale access
L_{loc} = locale location
L_{lay} = locale layout
H_a = human availability
H_t = human training and condition
H_e = human-operated equipment

The factors represented here do not ignore the socio-politico-economic (spe) factors contributing to them. In fact, the factors in the equation are largely a result of the spe factors. The spe factors are better understood and discussed by others.

The vegetative, structural, and human factors are linked. A structure of somewhat flammable characteristics may have a reasonable chance to survive if vegetation is distant, not too flammable, or does not cast embers readily. It may be feasible to have human intervention at the time of fire. On the other hand, a structure of resistant materials and shape may have a low probability of survival if proximal vegetation is flammable and this as well as other factors preclude the advisability of having humans there during a fire incident.

From personal observation, there seem to be groups of urban/ wildland fire problems based on the cultural-economic status of the owners or occupiers, as listed below:

Rancher/farmer
Subsistence
Moderate income
Well-to-do
Wealthy.

The rancher/farmer group generally present little problems concerning the protection form vegetation fires. Crop fields and grazing reduce flammable vegetation for all except short periods when grain crops ripen. Farmers and ranchers may also be more aware of the problems of fire in wildland situations. However, when active farming or ranching ceases, the vegetative complex may become very dangerous.

Subsistence structures may or may not represent a high risk class, depending on whether or not the residents have livestock. Many of these people appear to have moved to these locations to "live off the land" and avoid the high taxes of urban areas. Often these structures will have been built without permits, and they are not located on maps. Areas of these can constitute rural slums.

Structures owned by persons of moderate income often present severe wildland fire problems. These people have chosen to "live with nature" without realizing all the potential consequences, especially fire. Their structures may be substantial, often of flammable materials, and be set in very dangerous vegetative complexes. Additionally, maintenance of structures and vegetation may lag, contributing to general flammability.

Homes of the well-to-do vary greatly in their susceptibility to wildland fire, but why such a variance is difficult to assess. Probability it depends on their awareness of fire dangers, and their esthetic tastes. Some who have become aware of the problems and appreciate the prehistoric role and activity of fire in wildlands would build safer structures and manage fuels and vegetation. Others, in their naivete, would build sensitive structures in vegetation in which they allow dangerous fuel complexes to build up.

The very wealthy tend to have less dangerous situations, as the structures may be of less flammable materials and be surrounded by landscaped and well-maintained grounds. There are many exceptions to this, and we occasionally see losses of very expensive homes.

VEGETATIVE FACTORS

The six vegetation factors listed in equation 1 are those which contribute to the combustion and fire behavior of wildland fuels. All these attributes contribute the combustion, fire behavior, and ultimately to the potential for wildland fires to lead to the destruction of structures. Often, it is the combination of two or more of the attributes that lead to the dangerous properties of fuel complexes.

Fire behavior, and thus the potential for fires to cause damage to or loss of structures, depends on the properties of the vegetation given in the equation. Obviously, we must consider both the living and dead vegetative material, as each has its own characteristics which contribute to or impede fire spread.

Chemistry

Chemistry of vegetation is the most basic of the properties. If vegetation were not of flammable material, then there would be no need to worry about the other properties. The major structural components of vegetation are cellulose, hemicelluloses, and lignin.

Two other groups of components are of great importance in the flammability of vegetative materials - volatile compounds and ash components. Volatile compounds add greatly to the ability of vegetative materials to support flaming combustion and may contribute to the ability of embers to continue burning as they are transported through the air to a new site where they may initiate other fires, whether in vegetation or in structures.

Ash components, as the term indicates are those left after combustion of the vegetative material in a muffle furnace. The ash components can act to retard flaming combustion, but low amounts can enhance glowing combustion.

Moisture Content

We are all aware of the importance of moisture content in limiting the combustibility of vegetation. Living vegetation is generally higher in moisture content than dead vegetation. Active vegetation has a moisture content of 50 to 400 percent, whereas dead vegetation can be from essentially zero percent to several hundred percent. The effect of moisture on combustion is to retard the process.

Particle Size, Density, and Shape

The size of a particle affects its ease of ignitability, rate of exchange of moisture, and the ease with which it might be lofted as an ember. For a given quantity of fuel, the amount of surface exposed for combustion or sorption of moisture varies inversely as the transverse dimension, the diameter in the case of most woody stems. For needles or leaves, which may be triangular or flat rectangles, it would vary as the inverse of the height or thickness. A measure of particle dimensions often used is the surface area-to-volume ratio, s, with the dimensions of L^2/L^3, or L^{-1}.

Compactness

Compactness is the degree to which the fuel particles are packed together, and is called the packing ratio, b. Beta is the volume of fuel per unit volume of space, or can also be calculated from the ratio of the density of the fuelbed to the density of the fuel particles. Packing ratios of 0.01 to 0.001 provide for optimal fire spread in fine fuels, but higher ratios are optimal for larger fuels.

Fuel Arrangement

Important factors in fuel arrangement are continuity, both horizontal and vertical, and homogeneity. If fuels are continuous, then an easy pathway is provided for fire spread. Homogeneity describes the degree to which all sizes and kinds of fuel particles are distributed within the fuelbed. Spread models generally assume even;y distributed fuels complete homogeneity, which is generally not the case.

Quantity

The amount of fuel present is obviously important. However, as the amount of fuel becomes more compacted beyond a certain point, fire spread may be impeded, as is evident from the effect of packing ratio on spread. Thus, compacting fuel by crushing or chipping may be a treatment which is partially effective in reducing fire hazard. Quantity is usually measured in kilograms per square meter, metric tonnes per hectare, pounds per square foot, or tins per acre.

STRUCTURAL FACTORS

Structural factors include the materials, shape factors, or how the materials are put together, location, and protection devices. I'll leave the structural factors to those dealing with that subject in this conference.

HUMAN FACTORS

Human intervention at the time of the fire is another important factor in the survivability of structures. The first consideration in whether or not humans will or should be at the site is the safety of the individuals. Second would be the probability of saving the structure through their intervention. Both of these factors are dependent on those factors given above. The major differences are whether the individuals will be firefighters or homeowners. Factors that will be important in the differences are availability, training, conditioning, equipment, and supplies.

CONCLUSIONS AND REMARKS

Optimistically, we can look for changes to occur in the vegetation, structures, and location characteristic that will lead to improvement in the survival probability of structures. The pessimistic outlook is that the changes will occur only after some real disasters leading to the loss of many human lives. The changes will then come about through lawsuits filed against county and planning commissions for allowing structures and subdivisions to be built in such locations and of such materials and shapes with such dangerous vegetation that the probability of disaster is high.

FOREST FIRES AND FIRE MANAGEMENT IN TURKEY

Mehmet Serez

Professor Doctor
Department of Forest Entomology and Protection

Faculty of Forestry, University of Karadeniz, Trabzon, Turkey

FDC: 431/432: (560)

SUMMARY

The main destructive factor in Turkish Forest is forest fires. Between 1941 and 1987, 40.695 fires occured. Also between 1966 and 1987, total burned area is 292.983 hectares. All forest in Turkey are publiciyowned. As a result of this all prevention and control measurements are in the concern of the Forest Service.

A total of 41% of the forest fires are occuring in the Aegean, 24% in the Mediterranean, 22% in the Marmara Region and 13% in the other regions. In these regions, as at 27 September 1988, a total of is 15.512 hectares of the forest area burned. Reasons for forest fires: 25% negligence, 26% intentional, %1 lightning, 48% from factors whose reasons are unknown.

Keywords : Forest fires, Turkey, statistical data, organization, fire fighting

STATISTICAL DATA ON FOREST FIRES

Kinds of forest fires

As known forest fires are classified as ground, surface, and crown fires. In Turkey we have surface and crown fires. Between 1941 and 1987, 40.695 fires occured in Turkey forests. 81 percent of all these fires were surface fires.

Statistical data between 1981 and 1987

The statistical data on forest fires in Turkey are given in Table FF1, FF2, FF3 and FF4.

Causes of forest fires

The main causes of forest fires in Turkish forests are human-being (%98.8). The reason of the great number of forest fires is unknown (%46.6). But in fact the high majority of the unknown are incendiary in Turkey.

Approximately 1/3 of Turkish populace is living either within the forest, on the edge of the forest, or at a distance of 10 km. from the forest.

The socio-economic level of the people which are living in or near the forest, is highly below the standart of living. So these people would like to use the forest without any limitation for their survival. They start fire for reasons like acquiring new grazingland, clearing for new farmland, revealing certain processes in the forest which violate current laws and regulations, etc.

Some measurements such as, different kinds of hand works, organization in production, governmental funds to supply their needs, etc. Should take to improve of the socio-economic level of the people living in forested areas.

ENVIRONMENTAL CONDITIONS INFLUENCING FIRE DANGER

Weather conditions

Some climatic elements in some selected localities of Mediterranean, Aegean and Marmara regions are given on Table FF6. In these mentioned regions especially sumer drought accompained by high air temparature and low relative humiditiy, set the stage for the most bad fires reducing the moisture content of all classes of forest fuels to abnormally low levels. Especially the highhest temperatures in these areas occur at 2 pm.

In Mediterranean region the wind of S, SE and SW are oceanal origin, and so they bring more humidity. The result is : no much fire. But the wind of N, NE and NW origin, bring dry air masses. So, this situation created severe fire seasons.

Forest vegetation

In Turkey the altitute of land varies from 0 m to 5165m. The forest vertically lies between 0-2000m.

The total area of Turkey is 77 056 192 hectares. 26.21 percent of these land are covered by forest (20 199 296 hectares).

The tree species of Turkish forests are given on Table FF9 by hectares.

Fire Season

In different parts of Turkey, we frequently notice almost two characteristic types of fire season.

(1) Short fire season: This is well illustrated in Black-sea and Marmara regions. In Black-Sea region July-August, and in Marmara region June-August are the peak points.

(2) Long fire season: Mediterranean and Aegean regions are typical examples. It continues about 5-8 months, but some part of these regions has year-long fire season.

Endangered areas in Turkey

It is obvious that the forest fires are very important damaging factor in Mediterranean, Aegean and Marmara regions in Turkey. Total number of fires are 21 470 in Turkey between 1966 and 1987. And percentages of these fires are: Mediterranean region %25.6, Aegean region %30.5, Marmara region %17.7, and other regions %26.2. Also between 1966 and 1987 total burned area is 292 983 hectares. And percentages of these areas are: Mediterranean region %22.0, Aegean region %33.1, Marmara region %22.0, other regions %22.9.

IMPORTANCE OF FOREST FIRES IN THE FOREST POLICY

Comparisons between forested area and burned area

Comparisons of size of per fire, and burned portion of forest area between 1941 and 1985 in Turkey shows that between 1941 and 1960 both size of per fire, and burned portion of forest area were almost very high. But after 1961 all figures are decreasing, because of the regulation of fire prevention, and control works in Turkish forests.

Discussion of burned wildland

According to the researches realized in forest fires regions, fire did much damage especially in Mediterranean and Aegean regions over the centuries. The effect of fires on the soil, the microclimate and animal fauna are other factors that should be regarded in addition to this overall destruction of forests.

At the Mediterranean and also in Aegean regions, there are very few areas that are not burned between the sea level and an

altitude of 500 meters. Almost every old cluster pine (*Pinus brutia*) in these areas have a clear indication of fire on the lower part of their body close to the roots. As one goes higher in this region, the density of fires decrease, and one can rarely come across unburned areas at 1100 meters and above.

Since those areas once destructed by fires cannot be renovated naturally, this leads to brushwood covering on such areas very easily. It is for this reason that the burned areas at the Mediterranean and Aegean regions should be afforested on an overall basis. Otherwise, this would lead to soil erosion caused by heavy rainfall on the slopes, and thus these areas shall turn into calcareous formations.

But on the other parts of Turkey, and also in Marmara region, the forest fires are not so destructive on wildland, because of almost suitable climatic conditions.

Forest species threatened by fire

The natural distribution of *Pinus brutia* forests are lies on the coastal slopes almost between the sea level and 1250 m altitude in Mediterranean, Aegean and Marmara regions in Turkey. Especially in the Mediterranean region also *Pinus nigra* and *Cedrus libani* accompained *Pinus brutia* stands in upper altitude. The Maquis formation are also distributed all over the areas. The broadleaves, especially Oak, Chesnut and Peech are also present in pure or in mixed stands on these areas. So, the forest fires do damages the above mentioned species in all time.

Pinus brutia stands are very susceptible to fire during all their life time. *Pinus nigra* and *Cedrus libani* are the second coniferous species which damaged by fires. In broadleaves the Oak is the first, and Chestnut and Beech are the second species influenced by fires in Turkey.

The vegetation types-forest fire relationship are given in Table FF14 according to the results data between 1960 and 1985 in Turkey.

NATIONAL FOREST ORGANIZATION AND PRESENT ACTIVITIES AGAINST FIRES

National forest organization

Forest Service is under direction of the Ministry of Agriculture, Forest and Rural Affairs. The actual law gives the details of organization and function of Forest Service.

Forest Protection and Fire Control Department

This department is a major unit of General Directory of Forestry and it has three sections.

- Forest Protection. All agents damaging to forest exluding fire and pests.
- Prevention and Control of Forest Fires.
- Control of Forest Pests.

Present activities of Forest Service against fire

Prevention and Control of Forest Fires Section has manpower equipment and tools which are given below.

	Number
Ready force team	148
First attack crew	640
Fire labor	17000
Fire lookout	780
Water reservoir	55
Power equipment	659
VHF Radio	2582
Tools	73164
Power chain saw	322
Telescope	384
Mask	140
Unburned clothes	16

This section has built some roads and telephone lines.

Firebreak	8941 km
Fuelbreak	5486 km
Fire lookout road	1954 km
Telephone line	10746 km

Turkish Goverment is preparing Development Plan for every 5-year. The items from latest plan deals with forest fire prevention and control are given below.

Items	Number	km	Amount (1.000.000TL.) (x)
Fire lookout	250	-	375
First attack crew station	50	-	225
Water reservoir	75	-	375
Equipment and tools	1875	-	1002
VHF Radio	8483	-	8300
Radio station	5	-	990
Fire danger station	50	-	43
Firebreak and fuelbreak	-	2500	625
Telephone line	-	1500	75
Other			323
		TOTAL :	12333

(x) TL. : Turkish Lira. According to 1982 prices.

PROPOSALS FOR PREVENTION

Prevent arson fires

As we mentioned above, the main causes of forest fires in Turkish forest is arson (incendiary) fires. The people start arson fires for many purposes. Also in some important years, such as general election, senate election, etc. are the time to start arson fires in Turkish forest. So, both the numbers of fires and area burned increasing during such years.

To prevent arson fires in Turkish forest is a very difficult job. As we mentioned above, to develope the socio-economic level of people, is the first and important way to solve the problem. The people which are living in or near the forests must not look the forests as a main resource of grazing or to arable land.

Education

The primary problem in preventing forest fires in Turkey is humanbeing. So, one of the best way to reduce the number of fires is to find out the real reasons why people start fires. But it is often difficult to obtain this information.

The result of census in 1980 showed that over 6-year old population is 37 601 019 in Turkey. And 67.2 percent of these population are literate. But this percentage are almost low in villages, and especially in forest areas. Besides this, as we mentioned above, the socio-economic level of the people which are living in these areas, highly below the standart of Turkey. So, the best way to reach the result, is to incerease the socio.economic level of the people living in forested areas. To parallel this, educiation must be taken into consideration. Especially the organization to prevent

forest fires and forest must start in schools. Also the regulation of use of wildland is very important in preventing man-caused fires.

Prescribed burning

Prescribed burning is not use widely in Turkısh forests. Only for reforestation, the Forest Service using prescribed burning for to eliminate the unuseful materials on the areas. But, for many years farmers using this method for burning the remaining materials on their own agricultural lands.

Fuel management

In Turkısh forests, the fuel management are applied in forested areas almost widely in many years. Important fuel management activities which applied in Turkish forests are given below.

(1) All ignitable fuel in limited areas removal. Cleared and burned road sides, railway and recreation areas are some examples.

(2) Area fuel reduction mostly applied under silvicultural methods. For example, in reforestation, to care of stands, and for management the forests all silvicultural methods are taken into consideration. Especially in the forest fire regions, the mixed forests (coniferous + broadleaves) is our main objective.

(3) It is very expensive to remove all ignitable fuel in fire hazard areas. So, firebreaks and fuelbreaks are still the best way to break down the forest fuels in the fire regions. Almost last 15 years Forest Service gave more attantion to these barriers.

(4) Forest disasters of wild-fire, hurriance and insect epidemics often create dangerous fuel volumes of dead timber over extensive areas in Turkey. Forest Service immediately take care of to remove the materials from the forest.

Legislation

In Turkısh new constition (Dated : 7/11/1982, Nr.2709) has a section for forest, and people living in or near the forests. In this constition also forest fires take place. The first serious public effort to control fires was in "Forest Law" (Dated : 18/2/1937, Nr.3116). After that in 8/9/1956, a new Forest Law (Nr.6831) accepted by the Parliament. On 23/9/1983 (Law Nr.2896), only the section 71 of the forest Law (Nr.6831) is changed.

Law enforcment

Turkish constitution (Section 169) orders the reforestation of fire burned areas. The constitution also prohibid husbandary and animal breeding in fire burned areas.

In Turkısh Forest Law (Nr.6831), has some enforcment sections (Nr.104-107) for forest fires.

FIGHTING FOREST FIRES

Fire observation

It is necessary, especially in the fire seasons, to observe the forest continously. For this objective, 780 fire observation towers have been set up on hills dominating the forests. At these towers, binoculars are used for observation and to determine the location of a fire, limbus is used. Because the fire towers are at a distance from electric energy networks, a portion of these towers are obtaining there energy needs with a solar energy system.

The First Intervation and Ready Force Teams

In putting out forest fires, 12-15 person "first intervation" and places where there will be a tendency for the fire to grow,40-50 person "ready force teams" have been formed in order to make the first intervention againts the fire without losing time.

These teams have all kinds of fire fighting materials and vehicles and during the fire season, they kept ready at any moment for fighting duties. The number of fire fighting workers in these teams is 17.000, the number of first intervention teams is 640 and the ready force teams is 148.

Airplane Usage

Extinguishing instruments were used from the ground for forest fighting in Turkey up until 1985.

As of 1985, a combination of extingushing metods from the ground and from the air have been applied and airplanes started to be utilized in fighting forest fires.

In fighting forest fires, emptying water (1-800 liters) on the top of the fire is utilized in extinguishing or cooling the fire. This application has been started at İzmir and Çanakkale Forestry

Regional Directoretes that are most sensitive regions to forest fires. Also it was added to Muğla Forestry Regional Directorate in the Aydın Regions Services are carried out by three fleets composed of three extinguishing and one reconnaissance plane. The planes are rented from the Turkish Aviation Associations.

Helicopter Usage

In 1987 helicopters were purchased by the General Directorate of Forestry. The speed of these helicopters in 210-260 km./hour and they can remain in the air for 3.00-4.15 hours and can carry a load of 1.130-1.800 kg. These helicopters are currently being used in the fire prevention and fire fighting services at Muğla, Antalya, İzmir, and Çanakkale Regional Directorates where close to one half (48%) of the forest fires occur in Turkey. An Aviation Group was formed that is attached to the Forest Protection and fire Fighting Department Chair-manship. Forteen pilots and seven machine repairmen are employed under contract for the helicopters.

Use of Water Sprinkler Truck

There are 82 forest fire water sprinkler trucks and they continue to be purchased in the annual programs. These trucks are able to carry a capacity of 2000 liters of foam tank and materials together with fire fighter workers and they are able to work under difficult and conditions.

Construction of Man-Made Pool or Basin

Water is effective in extinguishing forest fires, but is not always possible to obtain is sufficient amounts or when needed in the Mediterranean and Aegean regions. For this reason, in the places where needed, basins and man-made pools are constructed in the annual programs. As of the end of 1987, 81 man-made pools had been constructed.

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TABLE FF1. Number and area

Please read the attached notes before comleting the table	1981	1982	1983	1984	1985	1986	1987
	(Number)						
A. Number of fires (Total)	982	951	968	1433	1793	1527	1310
B. Area burned by type of land	(Hectares)						
Total area, of which:	5470	4017	3556	7358	26007	11037	10746
Forest and other wooded land	5470	4017	3556	7358	26007	-	-
- High forest	4525	2976	2795	5418	14074	-	-
- Coniferous	4525	2976	2795	5418	14074	-	-
- Coppice and coppice with standards	945	1041	761	1940	11933	-	-

Remarks: All forest in Turkey are publicly-owned.

Date supply by: General Directory of Forest Service in Turkey.

TABLE FF2. Causes of Forest Fires in Turkey

	Number							Hectares						
	1981	1982	1983	1984	1965	1986	1987	1981	1982	1983	1984	1985	1986	1987
A. Basic information														
Know causes, of which:	403	444	495	720	898	687		2638	1879	1793	4326	14890		
- Human causes	384	416	475	688	851	627		2624	1849	1780	4310	14820		
-Arson	202	58	199	260	319	201		1332	194	901	1632	10508		
-Negligence	182	358	276	428	532	426		1292	1655	879	2678	4312		
- Natural causes (lightning)	19	28	20	32	47	61		14	30	13	16	70		
Unknown causes	529	507	473	713	895	838		2832	2138	1763	3032	11117		
TOTAL	982	951	968	1433	1793	1526		5470	4017	3556	7358	26007	11037	10746

TABLE FF3. Losses from Forest fires in Turkey.

Estimated losses	1981	1982	1983	1984	1985	1986	1987
A. Total volume of non-recoverable wood, of which:							
- Sawlog-size ($1000m^3$) (overbark)	284	86	331	172	484	247	378
- Other (1000 Ster) (x)	147	61	74	55	699	656	144
	(Unit 1 000 000 TL.) (xx)						
B. Total value of which:	517	382	565	2596	10402	4697	8654
- Wood and other tangible losses	517	382	565	2596	10402	4697	8654

Describe briefly the method used to evaluate losses (see note):

(x) 1 Ster = $1m^3$ wooden material

(xx) TL. = Turkish Lira

Total value = The market value of materials + Fire suppression expenses + Reforestation cost.

TABLE FF4. Expenditures on forest fire prevention and control in Turkey

	1981	1982	1983	1984	1985
	(Unit 1 000 000 TL.)				
Total, of which by	1032	1351	2798	4180	8470
- Forest Service	1032	1351	2798	4180	8470

Remarks and supplementary statistics:

TABLE FF5. The major causes of forest fires between 1960 and 1998 in Turkey (x)

YEARS	NUMBER OF FIRES				TOTAL
	Lightning	Arson	Negligence	Unknown	
1960 - 1975	59	3457	2485	4154	10155
1976	10	131	199	362	702
1977	12	770	15	818	1615
1978	4	276	266	576	1122
1979	19	367	260	654	1300
1980	14	324	185	569	1092
1981	19	202	182	579	982
1982	28	58	358	507	951
1983	20	199	276	473	968
1984	32	260	428	713	1433
1985	47	319	532	895	1793
1986	61	201	426	839	1527
TOTAL	325	6564	5612	11139	23640
MEAN	12	243.1	207.8	412.5	875.5
%	1.37	27.77	23.74	47.12	100.0

(x) Forest Service Statistics: 1960-1986, Ankara

TABLE FF6. Some climatic elements in some selected localities at fire susceplible areas in Turkey (x)
(Almost in last 50 years)

Climatic elements	Mediterranean Region		Aegean Region		Marmara Region	
	Adana	Antalya	İzmir	Muğla	Canakkale	İstanbul
Highest temperature (°C)						
May	41.3	38.7	37.6	35.6	34.4	34.1
June	42.3	41.5	41.3	37.8	36.0	39.2
July	44.0	43.9	41.9	40.0	38.2	38.3
August	45.6	44.6	42.7	41.2	38.7	40.5
Septimber	42.7	42.5	37.2	38.1	34.6	37.5
Mean temperature (°C)						
May	21.4	20.4	20.4	17.5	17.3	16.4
June	25.2	25.1	25.0	22.5	21.8	20.8
July	27.6	28.1	27.6	26.0	24.6	23.2
August	28.0	28.0	27.2	25.7	24.4	23.2
September	25.3	24.8	23.2	21.5	20.6	19.6
Mean relative humidity (%)						
May	67	68	62	58	72	73
June	66	61	55	46	65	70
July	68	58	52	39	61	69
August	67	59	53	40	61	70
September	63	58	58	47	66	73
Mean precipitation (mm)						
May	47.5	29.8	34.0	46.8	30.1	31.1
June	19.6	9.4	9.7	21.9	24.1	23.2
July	4.9	3.4	1.5	6.8	11.2	21.4
August	4.6	2.4	2.9	7.3	8.2	24.3
September	15.4	13.2	11.0	18.5	25.6	47.8
Annual precipitation (mm)	641.6	1064.8	698.0	1206.4	625.0	677.4

(x) Statistical Yearbook of Turkey 1983.
Prime Ministry State Institute of Statistics, Ankara.

TABLE FF7. Forest area and forest types of Turkey[x]

QUALITY	HIGH FOREST				COPPICE	TOTAL Forest Area	%
	Coniferous Hectares	Broadleaves Hectares	Mixed Hectares	TOTAL Hectares	Hectares	Hectares	
PRODUCTIVE	4 564 835	1 087 169	605 695	6 176 899	2 679 558	8 856 457	43.85
NONPRODUCTIVE	3 951 137	497 352	309 219	4 757 708	6 585 131	11 342 839	56.15
T O T A L	8 515 172	1 584 521	914 914	10 934 607	9 264 689	20 199 296	100.00

(x) Forest Inventory of Turkey 1980.
Ministry of Forestry, Directory of Forest Service,
Nr.13/630, Ankara. 127 pp.

TABLE FF8. Percent of forest areas at Geographycal Regions in Turkey[x]

NAME OF GEOGRAPHYCAL REGION	FORESTED AREA %
Black-Sea	24.90
Mediterranean	24.18
Aegean	16.75
Marmara	12.76
East Anatolia	10.83
Central Anatolia	7.54
South-East Anatolia	[illegible].04
T O T A L :	100.00

(x) Bozkurt, A.Y. and Göker, Y. 1981. Orman Ürünlerinden Faydalanma. İstanbul Üniversitesi Orman Fakültesi Yayınları, 2840/297, İstanbul. XV 432+pp.

TABLE FF9. Tree species and their areas in Turkish forests(x)

TREE SPECIES	HIGH FOREST			COPPICE FOREST		
	Productive Hectares	Unproductive Hectares	TOTAL Hectares	Productive Hectares	Unproductive hectares	TOTAL Hectares
Pinus brutia	1 784 068	1 311 996	3 096 064			
Pinus nigra	1 396 511	807 870	2 204 381			
Pinus silvestris	475 219	262 973	738 192			
Abies spp.	128 249	55 631	183 880			
Picea orientalis	82 361	53 598	135 959			
Cedrus libani	67 850	31 475	99 325			
Juniperus spp.	70 515	855 307	925 822			
Pinus pinea	10 721	9 828	20 549			
Other coniferous	488	1 187	1 675			
Mixed coniferous	548 053	561 272	1 109 325			
Fagus spp.	495 842	118 773	614 615	32 208	19 784	51 992
Quercus spp.	173 573	206 545	380 118	2 049 588	2 171 287	4 220 875
Carpinus spp.	1 254	2 274	3 528	231	418	649
Alnus spp.	23 120	13 069	36 189			
Populus spp.	3 362	3 746	7 111			
Costane sativa	6 720	4 479	11 199	3 377	448	3 825
Fraxinus spp.	1 661	1 851	3 512			
Eucalyptus spp.	2 429	-	2 429			
Liquidamber orientalis	980	357	1 337			
Other broadleaves	663	1 575	2 238	931	1 694 898	1 695 829
Mixed broadleaves	297 565	144 680	442 245	593 223	2 698 296	3 291 519
Coniferous+broadleaves	605 695	309 219	914 914			
T O T A L	6 176 899	4 757 708	10 934 607	2 679 558	6 585 131	9 264 689

(x) Forest Inventory of Turkey 1980.
Ministry of Forestry, Directory of Forest Service,
Nr. 13/630, Ankara. 127 pp.

TABLE FF10. Tree species and their percentage in Turkish forests(x)

CONIFEROUS	%	BROADLEAVES	%
Pine	38.5	Oak	25.9
Fir	6.8	Beech	8.5
Spruce	2.0	Hornbeam	2.7
Cedar	3.5	Chestnut	1.4
Juniper	3.5	Alder	0.9
Other coniferous	0.1	Poplar	0.8
		Lime-tree	0.5
		Ash-tree	0.4
		Other broadleaves	4.5
T O T A L :	54.4		45.6

(x) Bozkurt, A.Y. and Göker, Y. 1981. Orman Ürünlerinden Faydalanma. İstanbul Üniversitesi Orman Fakültesi Yayınları, 2840/297, İstanbul. XV+432 pp.

TABLE FF11. Regional distribution of forest fires between 1966 and 1985 in Turkey (x)
(in number and in hectares)

YEARS	TOTAL Fires	Area	Mediterranean Region		Aegean Region		Marmara Region		Other Region	
1966-1975	6676	117 379	1713	38 572	2243	38 572	1032	23 014	1638	26 129
1976	702	6 396	88	520	312	2 357	117	2 293	185	1 226
1977	1615	43 076	248	8 402	476	6 354	352	12 376	539	15 944
1978	1122	13 233	335	4 295	338	4 004	185	2 077	264	2 857
1979	1300	34 480	436	6 895	401	20 164	252	2 958	211	4 463
1980	1092	10 248	287	2 436	356	3 010	200	1 942	249	2 860
1981	982	5 470	248	1 407	275	1 625	155	894	304	1 544
1982	951	4 017	299	878	215	943	163	860	274	1 336
1983	968	3 556	302	915	281	1 160	159	883	226	568
1984	1433	7 358	420	2 087	343	1 825	203	1 557	387	1 886
1985	1793	26 607	395	2 302	445	9 829	339	10 706	554	3 170
TOTAL	18634	271 220	4771	59 831	5685	89 843	3297	59 560	4881	61 986
MEAN	931,7	13 561	238,5	2 992	284,3	4 492	164,9	2 978	244,0	0 099
%	100,0	100.0	25,6	22.0	30,5	33.1	17,7	22.0	26.2	22.9

(x) Forest Service Statistics : 1966-1985, Ankara.

TABLE FF12. Comparison size of per fire and burned portion of forest area between 1941-1988 in Turkey[x]

YEARS	Number of Fires	Area Burned (Hectares)	Hectares Burned per fire	Burned portion of forest area %
1941 - 1945	4074	357 970	87.87	1.7722
1946 - 1950	4046	323 147	7^.87	1.5998
1951 - 1955	4568	162 104	35.49	0.8025
1956 - 1960	3562	111 108	31.19	0.5501
1961 - 1965	2975	41 657	14.00	0.2026
1966 - 1970	2797	54 028	19.32	0.3154
1971 - 1975	3879	63 704	16.42	0.3154
1976	702	6 396	9.11	0.0317
1977	1615	43 076	26.67	0.2133
1978	1122	13 233	11.79	0.0655
1979	1300	34 480	26.52	0.1707
1980	1092	10 248	9.39	0.0507
1981	982	5 470	5.57	0.0271
1982	951	4 017	4.22	0.0199
1983	968	3 556	3.67	0.0176
1984	1433	7 358	5.13	0.0364
1985	1793	26 007	14.50	0.1288
1986	1527	11 037	7.23	0.0546
1987	1310	10 746	8.20	0.0532
TOTAL	40696	1 289 344	-	
MEAN	865.8	27 432	31.68	

(x) Forest Service Statistics : 1941 - 1988

TABLE FF13. Tree groups and percent of fire number between 1960 and 1985 in Turkey[x]

TREE GROUPS	Percent of fire number
Pine	71.8
Other coniferous	2.6
Coniferous + broadleaves	2.3
Oak	6.0
Maquis	2.4
Beech	0.5
Mixed broadleaves	1.0
Debris + Piled slash	13.4
T O T A L :	100.0

(x) Forest Service Statistics : 1960-1985, Ankara.

TABLE FF14. Central and provincial organization of Forest Service[x]

A. CENTRAL ORGANIZATION:

General Directory of Forestry

Assistant General Directory of Forestry

MAJOR UNITS	CONTROL AND ADVISORY UNITS	AUXILIARY UNITS
1. Forest Protection and Fire Control	1. Inspection Council	1. Personal
2. Forest Cadastre and Ownership	2. Research-Planning and Coordination	2. Administry and Financial Affairs
3. Forest Administration and Planning	3. Juridicial (Legal) Advisory	3. Education
4. Management and Marketing		4. Civil Defence
5. Nurseries and Seeds		
6. Aforestation and Silviculture		
7. National Parks		
8. Construction and Reinforcement		

B. PROVINCIAL ORGANIZATION:

24 Forest Conservatory
207 Forest Districts
1120 Forest Subdistricts
2 Forest Reserch Institute
31 Forest Nurseries

(x) Forest Service Organization Law.
Dated : 8/11/1985, Nr.3224.

TABLE FF15. Legal orders and politic differences and their influences on forest fires in Turkey[x] (Between 1968-1987)

YEARS	Number of fires	Area burned Hectares	NOTES
1968	387	7540	
1969	714	16364	General election and new law (constitution) proposal.
1970	790	15019	New constitution proposal and amnesty Law are in Parliament.
1971	651	7532	
1972	440	6914	
1973	1208	17002	General election. Statute Nr.1744 and Forest amnesty put into force.
1974	769	14743	
1975	811	17516	Senate election (partial).
1976	702	6396	
1977	1615	43076	General election.
1978	1122	13233	
1979	1300	34480	Partial election for Senate and intermediary election for parliament.
1980	1092	10248	
1981	982	5470	Extraordinary period of 12/9/1980.
1982	951	4017	
1983	968	3556	
1984	1433	7358	
1985	1793	26007	
1986	1527	11037	
1987	1310	10746	General election.

(x) Çanakçıoğlu, H. 1985. Orman Koruma (Forest Protection). İstanbul Üniversitesi Orman Fakültesi Yayınları, Nr.3315/376, İstanbul. XIX+486 pp.

LE BRULAGE DIRIGE: EFFICACITE DE LA TECHNIQUE BRUNIR ET BRULER DANS LES FORMATIONS FORESTIERES MEDITERRANEENNES

Jean-Charles Valette, Eric Rigolot et Joël Maréchal

Unité "Prévention des Incendies"
Station de Sylviculture Méditerranéenne
Département des Recherches Forestières
Institut National de la Recherche Agronomique
Avignon, France

FDC: 436: 414.12: 432.16: (4-015)

RESUME

Pour réduire la combustibilité des formations forestières méditerranéennes, les strates basses, herbacée et surtout arbustive, sont **broyées**. Mais elles peuvent être également **brûlées** (brûlage dirigé), **brunies** (application de phytocides) et **même broutées** (pâturage intensif contrôlé). L'objet de cette communication est d'illustrer l'intérêt de la méthode **brunir et brûler** en analysant la synergie entre les effets du feu et ceux du phytocide tout en indiquant les éventuelles incompatibilités.

SUMMARY

To reduce the combustibility of mediterranean forests communities, graminaceous and particularly shrubs are crushed (**broken**). But they can also be **burned** (prescribed burning), **browned** (use of herbicide) and even **browsed**. The aim of this paper is to describe the interest of the **brown and burn** method, to analyze the sinergy between the effects of the fire and those of the herbicide and to indicate the possible incompatibilities.

INTRODUCTION

Les formations forestières, autrefois

Les incendies, d'abord d'origine exclusivement naturelle, ensuite de plus en plus liés à l'activité humaine, ont toujours parcouru les formations forestières méditerranéennes et les ont fait évoluer vers des écosystèmes riches en espèces pyrophytes à un rythme propre à chacune d'entre elles.

Jusqu'à la fin du siècle dernier, les agriculteurs, pour amender leurs terres, et les pasteurs, pour entretenir leurs parcours, ont régulièrement employé le petit feu d'hiver dans des milieux où la strate arbustive était peu développée en raison de son exploitation permanente. Celle-ci, en effet, fournissait de nombreux produits et services domestiques ou artisanaux :
* le bois de feu et le charbon de bois,
* les fagots de branchages secs pour la cuisson des aliments,
* la litière pour les animaux, les branchages feuillés pour leur nourrir,
* les amendements pour les terres agricoles (légumineuses),
* les écorces à tan et à liège et les fruits forestiers,
* plantes médicinales ou aromatiques,
* toute une gamme de menus produits (balais, souches de bruyère, , etc...).

Ces pratiques ont assuré la protection des forêts dans les conditions socio-économiques de l'époque, même si des incendies dévastateurs venaient de temps à autre rappeler l'existence des périls.

Très liées à l'activité agro-pastorale, ces pratiques sont tombées en désuétude au fur et à mesure de l'exode rural et du départ des utilisateurs chevronnés. Les formations forestières se sont alors refermées et les friches se sont embroussaillées. Réalisé par ceux qui restaient, dans des milieux dont la structure conférait, au fil du temps, une combustibilité croissante, le petit feu a donné de moins en moins satisfaction et a provoqué un nombre croissant d'incendies, ceci a conduit les forestiers et les autorités publiques (préfectures, mairies) à strictement réglementer son emploi sans en bannir l'utilisation.

De nos jours

La poursuite de l'exode rural et de la déprise agricole s'accompagne d'un embroussaillement, parfois rapide, de terres que les exploitants qui demeurent ne peuvent plus entretenir. Le gel de certaines terres agricoles, programmé pour les années à venir, n'inversera pas cette tendance ; la continuité entre la couche de matière végétale morte qui s'accumule au sol et la strate arborée dont la valeur économique ne cesse de décroître, sera de mieux en mieux assurée.

Face à cela, les interventions sylvicoles actuellement réalisées pour la prévention des incendies de forêts, ont toutes pour objet de réduire la combustibilité des formations forestières. Cette combustibilité dépend des paramètres suivants :
* la richesse des espèces arbustives en huiles essentielles inflammables,
* les conditions édaphiques peu favorables (sols superficiels à faible réserve en eau, fort enrochement),
* la puissance des strates basses, herbacée mais surtout ligneuse,
* l'extrême sévérité des conditions climatiques estivales (vents violents et desséchants, température et siccité de l'air élevées).

Cette combustibilité peut être réduite en créant des discontinuités dans la couverture forestière destinées à limiter la propagation des incendies et, dans le meilleur des cas, à casser leur progression.

Le débroussaillement permet de réaliser ces discontinuités horizontales et verticales en créant des coupures de combustible, des zones sur lesquelles la phytomasse et le phytovolume sont réduits à son niveau minimum, voire même complètement supprimés (pare-feu à "sable nu") où les verticilles inférieurs des arbres sont élagués pour réduire les risques de feu de cimes.

Dans les zones forestières de production comme les peuplements de Pinus pinaster des Landes de Gascogne par exemple, ces opérations sont plus aisées à réaliser, les conditions y sont dans l'ensemble moins défavorables. De plus, elles se justifient financièrement car elles s'inscrivent dans les opérations de protection de peuplements à forte productivité et à forte valeur économique.

En région méditerranéenne par contre, en particulier dans les zones de basse altitude, souvent fortement urbanisées (zone rouge), la justification économique de ces opérations ne réside pas dans la valeur des peuplements en terme de production de bois (en général faible, voire nulle) mais dans le rôle récréatif, paysager ou de protection des sols contre l'érosion. Dans ces secteurs, les collectivités territoriales françaises (état, régions, départements, communes) et même la C.E.E. consentent des efforts financiers considérables pour sauvegarder la couverture forestière. Pour des raisons à la fois écologiques et économiques, les opérations de débroussaillement ne sont qu'exceptionnellement réalisées en plein ; elles sont cantonnées, pour l'essentiel, en bordure des voies de circulation. Ces zones régulièrement entretenues constituent un réseau destiné non à bloquer passivement la propagation des incendies mais à assurer la sécurité des équipes de surveillance et de lutte et, lorsque les incendies ne sont pas trop puissants, à constituer des lignes d'arrêt ou d'attaque (contre-feu).

Le débroussaillement mécanique, réalisé à la main ou par des engins motorisés, est la méthode la plus utilisée pour entretenir ces coupures. La répétition dans le temps des opérations d'entretien, d'autant plus fréquentes que la strate arbustive est dynamique, conduit les services de gestion forestière, devant l'accroissement vertigineux des coûts :
* à chercher à optimiser les moyens matériels et humains qu'ils gèrent et à adapter le volume de ces moyens à la valeur des peuplements à protéger,
* à s'interroger sur la faisabilité, l'efficacité à court et moyen terme et à la rentabilité de méthodes comme le brûlage dirigé et l'application de phytocides, voire le pâturage intensif contrôlé, dans les conditions socio-économiques et écologiques actuelles.

Ces méthodes seraient employées lorsque les conditions ne permettent ou ne justifient pas le débroussaillement (relief trop accidenté, mécanisation peu aisée du chantier, faible valeur des peuplements,...). Leur emploi est également envisageable pour constituer, en bordure de la coupure, une zone où la réduction des strates basses entraînera la réduction de la puissance des incendies et un amélioration de la sécurité des agents. Cet élargissement de la coupure, gage de son efficacité, n'est réalisable que si les coûts induits demeurent en rapport avec la valeur des formations. Enfin, ces méthodes peuvent s'intégrer dans un plan d'aménagement agro-sylvo-pastoral dans lequel chaque intervention satisfait à plusieurs objectifs, entretien des parcours et prévention des incendies, ouverture du milieu et éclaircies, protection des forêts contre les incendies et tourisme.

Le brûlage dirigé, employé seul ou combiné avec les autres méthodes, pourrait être également employé pour entretenir les peuplements adultes, à condition qu'il n'altère pas leur état sanitaire, ou pour préparer la régénération naturelle en réduisant la concurrence vis à vis des semis, voire en accroissant la production de graines.

Les travaux de recherches

Dans le monde

Des travaux très importants ont été réalisées en Amérique du Nord notamment par :
* C.E. Van Wagner et M.G. Weber, sur le comportement du feu dans les forêts canadiennes et son utilisation pour la gestion des formations boréales, par exemple, les peuplements de *Pinus banksiana*,
* R.C. Rothermel et H.E. Anderson, sur la modélisation du feu et J.K. Brown et K.C. Ryan sur le brûlage dirigé et ses effets sur les différents composants des écosystèmes du Nord des Etats-Unis, les forestiers l'emploient pour entretenir les plantations de pins du Sud-Est et les pâturages extensifs de l'Ouest,
* S.G. Conard et A. Koonce, sur l'impact des incendies et du brûlage dirigé sur les écosystèmes californiens, en particulier le chaparral, dans lesquels des essais sont en cours ainsi que dans les chênaies sclérophylles.

Des travaux sont également réalisés en Australie, en Nouvelle-Zélande, en Afrique du Sud et en U.R.S.S.

En Europe

Les gestionnaires et les chercheurs forestiers du nord du bassin méditerranéen ont adopté une démarche commune :
* les portugais, autour de J. Moreira da Silva et F.C. Rego, ont réalisés de nombreux brûlages dans des formations à *Pinus pinaster* ; ils suivent des dispositifs dans des peuplements d'*Eucalyptus globulus*, *Pinus sylvestris* et *Quercus pyrenaïca* et envisagent d'en installer sous *Pinus pinea* et *Quercus suber* ,
* en Espagne, J.A. Vega étudie l'impact des incendies et du brûlage dirigé sur les plantations de *Pinus pinaster* et d'*Eucalyptus globulus*,
* dans les conditions socio-économiques grecques, où l'élevage caprin est demandeur d'espace, des expériences de brûlage dirigé et de pâturage intensif contrôlé ont été mises en place sous l'impulsion de L. Liacos,
* en France, des travaux ont été réalisés depuis 1981 sur la base de ceux de L. Trabaud et de nos connaissances sur le feu et l'efficacité des phytocides. Les principales formations à *Quercus pubescens*, *Quercus ilex*, *Pinus pinea*, *Pinus halepensis*, *Pinus pinaster* et *Pinus sylvestris* ainsi que le maquis à éricacées et la garrigue à *Quercus coccifera*, *Phillyrea latifolia*, *Thymus vulgaris*, *Rosmarinus officinalis* et *Brachypodium ramosum* sont étudiées.
* les forestiers italiens qui n'envisagent, pour l'instant, que quelques brûlages expérimentaux et prudents sous *Pinus halepensis*.

METHODES

Les dispostifs expérimentaux

Taillis vieilli de *Quercus pubescens* : Ollières85

Ce dispositif se situe dans le Quercetum pubescentis aceretosum où les landes de l'Aphyllanthion forment l'essentiel des sous-bois.

Cinq traitements ont été appliqués :
* le débroussaillement manuel, au cours de l'hiver 1984-1985, comme témoin,,
* le brûlage dirigé conduit par bandes successives, en Avril 1985,
* le même brûlage dirigé puis l'application de glyphosate (4320 g/ha) et de simazine (5000 g/ha) en Juin 1985,
* l'application des mêmes matières actives à la même dose en Octobre 1985 suivie d'un brûlage dirigé en Mars 1986,
* l'application de triclopyr (4830 g/ha) en Septembre 1985 suivie d'un brûlage dirigé en Mars 1986.

Peuplement mélangé de feuillus et de résineux : Mazaugues86

Ce dispositif se situe dans la même série de végétation qu'Ollières85. Toutefois, en raison de l'exposition (Nord-Nord-Ouest) et du gradient altitudinal (450 à 600 m), de nombreuses espèces de la série supra-méditerranéenne du chêne pubescent (Querceto-buxetum) sont présentes. De plus se superpose localement l'influence d'un déterminisme édaphique :
* dalle calcaire : garrigue à *Rosmarinus officinalis*, Rosmarino lithospermum,
* grès à ciment calcaire : faciès à *Erica scoparia*,
* sols plus profonds, acides et frais : faciès à *Pteridium aquilinum*,
* zones de suintements et sources : faciès à *Molinia caerulea*.

La strate arborée est très diversifiée : *Pinus pinaster*, *Pinus halepensis* et *Pinus sylvestris* de 15 à 25 m de haut ainsi que *Quercus pubescens*, *Quercus ilex*, *Salix sp.*, *Populus alba* et *Sorbus sp.* selon le site. La strate arbustive est très puissante et riche en *Spartium junceum* et *en Erica scoparia*. La strate herbacée est continue et riche en *Brachypodium pinnatum* et *Aphyllanthes monspeliensis*. *Avec Pteridium aquilinum*, ces strates constituent un tapis épais et dense à fort dynamisme, au moins dans les zones favorables (thalwegs).

Ce dispositif a été implanté au cours de l'hiver 85-86 sur une coupure de combustible créée en 1971 puis entretenue à la main en 1974 et 1979.
Trois grands types de traitement ont été appliqués :
* le débroussaillement manuel au cours de l'hiver 1985-1986,
* le brûlage dirigé par bandes successives en Mars 1986,
* le même brûlage dirigé suivi de l'application de glyphosate à 4320 g/ha en Juin 1986.

De plus, sur quelques parcelles où le feu ne pouvait être conduit, ont été appliqués le glyphosate à la même dose ou le triclopyr à 4800 g/ha.

Les techniques de traitement

Le débroussaillement manuel

Les individus de la strate arbustive sont coupés, aussi rez-terre que le permet l'enrochement superficiel, à la débroussailleuse à moteur tandis que la strate herbacée est fauchée. A la différence du débroussaillement mécanique qui broie les végétaux sur place et qui, temporairement au moins, accroît significativement la masse de matière végétale morte au sol, les rémanents sont mis en tas puis brûlés. Cette opération s'accompagne du relèvement du couvert arboré, de la suppression des fourches et des branches mortes.

L'application de phytocides

Compte tenu de l'hétérogénéité du milieu et pour s'assurer de l'homogénéité de la répartition de la bouillie, les parcelles ont été subdivisées en bandes de traitement de 5 m de large et d'une longueur égale à la largeur de la coupure, entre 20 et 25 m. Les traitements sont réalisés à la lance permettant de régler la forme du jet et raccordée, par un tuyau de 50 m de long, à une cuve tractée en bordure de la coupure, la pompe assure le brassage en cuve et une pression de 20 bars.

Le brûlage dirigé

Le brûlage par bandes successives est tout à fait adapté à la structure linéaire des coupures (Maréchal et Valette, 1988). Quelques jours avant le brûlage, la phytomasse et le phytovolume des strates basses sont évalués à partir des récoltes effectuées sur des carrés de 1 m^2. Lors de la mise à feu, des échantillons de litière sont prélevés puis transportés au laboratoire pour déterminer son indice de siccité. La température et l'humidité de l'air sont régulièrement mesurées tout au long du brûlage ainsi que la vitesse et la direction du vent, la largeur des bandes ainsi que l'orientation sont ajustées en fonction des fluctuations climatiques et des variations du phytovolume de la strate arbustive.

Brunir et brûler

Cette combinaison ne demande pas la mise en oeuvre de techniques particulières, seul l'ordre des opérations peut induire des ajustements :
* brunir puis brûler nécessite une application du phytocide systémique en automne, alors que les végétaux sont encore en activité, et un brûlage de fin d'hiver de façon à laisser le temps au produit de migrer dans les végétaux, ceci améliore leur combustibilité et permet de conduire des brûlages lorsque l'humidité atmosphérique est trop élevée,
* brûler puis brunir permet plus de latitude dans le choix de la période de brûlage, au cours de l'hiver, le phytocide systémique sera appliqué au cours de la saison de végétation suivante sur des rejets suffisamment développés.

Les techniques d'analyse

La strate arborée

Selon sa densité et son hétérogénéité, un état initial est établi par un inventaire en plein ou par échantillonnage (circonférence et hauteur totale). Les individus mesurés sont identifiés, leur état sanitaire (évolution des dommages foliaires, débourrement, rejets, ...) est observé à cadence soutenue au cours de la première saison de végétation qui suit les traitements. La circonférence et la hauteur des arbres jeunes sont mesurées à l'issue de cette saison, un premier bilan provisoire est établi. Cette opération est reprise à la fin de chaque saison de végétation, un bilan complet est établi après trois à cinq années d'observations.

La bande d'observation des strates basses

Compte tenu de l'extrême hétérogénéité de la végétation et afin de chiffrer l'évolution de la végétation, des bandes d'observation de 1 m de large sur 10 ou 20 m de long, subdivisées en carrés de 1 m^2, sont implantées sur la coupure dans les milieux les plus représentatifs. Un état initial est établi, il sert ensuite de référence pour les relevés annuels effectués à date fixe. Sur chaque carré, le recouvrement de chaque espèce est noté selon une échelle à 6 niveaux et sa hauteur est mesurée.
Ces données sont ensuite regroupées pour l'ensemble de la bande :
* fréquence des présences, en dixièmes ou vingtièmes,
* surface couverte sur les 10 ou 20 m^2 observés, en dm^2
* hauteur moyenne, (somme des hauteurs/nombre de présences), en dm,
* phytovolume d'encombrement sur 10 ou 20 m^2, (surface * hauteur), en dm^3,
* indice volumique = 100 * phytovolume actuel / phytovolume initial.

Des descriptions et des clichés photographiques complètent ces informations

Sur le dispositif Mazaugues86, la liaison entre le phytovolume mesuré par la méthode indiquée ci-dessus et la phytomasse sèche a été établie pour chaque espèce ou groupe d'espèces. L'objectif est de disposer d'un modèle, d'une méthode simple, non destructive et répétitive pour qualifier le potentiel calorifique d'une formation végétale et de juger de l'efficacité des travaux d'entretien des coupures de combustible ou de la nécessité de les reprendre, les données sont en cours d'analyses.

RESULTATS

La strate arborée

Grâce à la qualité du travail des agents qui ont réalisé le débroussaillement manuel et l'application, aucune blessure au collet ni aucune dérive ne sont observables.

La facilité d'emploi et l'efficacité du glyphosate ont permis de détruire les gourmands apparus sur la partie inférieure du tronc des *Quercus pubescens* sans atteinte du feuillage.

Les dommages foliaires provoqués par le feu se sont estompés au cours de la première saison de végétation et ont presque totalement disparu au cours de la seconde. Par contre, malgré la prudence avec laquelle les brûlages ont été conduits, les collets des troncs ont été suffisamment échauffés pour que les assises cambiales des individus à écorce fine soient nécrosées, et ceci que le feu ait été, au niveau de l'arbre, au vent ou à la recule. La mort progressive des brins tire-sève sur les cépées d'*Acer monspessulanum* et de *Phillyrea latifolia*, presque systématique sur le dispositif Ollières85 conduit, en deux ou trois saisons de végétation, à une explosion de rejets ne pouvant être contrôlés dans ce cas là par le phytocide appliqué avant que les rejets n'apparaissent.

Ce transfert d'une part importante de la phytomasse et du phytovolume de la strate arborée vers la strate arbustive va à l'encontre de l'objectif initial puisqu'il augmente la continuité entre le sol et les cimes au lieu de la réduire ; **l'entretien de la coupure par le feu est donc incompatible avec le maintien sur cette coupure d'individus à écorce fine au collet.**

L e s   s t r a t e s   b a s s e s

Le dispositif d'Ollières85

Le tableau ci-après présente, par traitement, l'évolution de l'indice volumique observé sur des bandes de 10 m².

	Herbacées						Ligneux					
	8503	8506	8510	8606	8610	8706	8503	8506	8510	8606	8610	8706
débroussail.	100	33	-	49	-	62	100	21	-	50	-	54
brûlage	100	17	-	97	-	94	100	22	-	71	-	94
feu+glypho.	100	56	1	8	6	13	100	9	-	5	7	11
triclo.+feu	-	-	100	113	95	107	-	-	100	20	21	49
glypho.+feu	-	-	100	57	7	67	-	-	100	5	5	5

Si en Juin 1985, la strate herbacée ne s'est reconstituée qu'au sixième de son état initial sur la parcelle brûlée et au tiers sur la parcelle débroussaillée, cet avantage pour le feu disparaît l'année suivante, l'apport fertilisant des cendres ayant activé la reconstitution de cette strate. La destruction des brins de *Phillyrea latifolia* par le feu entraîne l'apparition de rejets denses et vigoureux en 1986, ceci explique la reconstitution plus rapide des ligneux sur la parcelle brûlée que sur celle débroussaillée. La parcelle brûlée puis traitée au glyphosate avait retrouvé 56% de son stade initial lors de l'application de glyphosate. L'action de cette matière active est spectaculaire : *Brachypodium pinnatum* et *Festuca ovina* qui constituait l'essentiel du tapis herbacé sont éliminés. Les effets demeurent très nets en 1986 et 1987 et, même si le printemps de 1988 a été très favorable à la croissance des herbacées, ils sont encore observables en 1988 et 1989.

A la lecture du tableau, les résultats sur la parcelle traitée à l'automne 1985 et brûlée en Mars 1986 paraissent moins satisfaisants. Pourtant *Brachypodium pinnatum* et *Festuca ovina* sont éliminés, mais *Vicia sepium* a envahi la parcelle en profitant de la suppression de la concurrence des graminées. Toutefois, cette explosion, cette mutation de flore s'avère bénéfique dans le cadre de la protection des forêts contre les incendies ; l'appareil épigé de cette légumineuse disparaît en été (ceci explique le creux d'Octobre 1986). L'action du glyphosate sur les ligneux, en particulier sur les rejets de *Phillyrea latifolia* et d'*Acer monspessulanum* est remarquable.

Les effets de la combinaison triclopyr + feu étaient prévisibles, cette matière active est sans action sur les graminées. Le tapis a, au contraire, profité de l'apport en potasse par les cendres et de la réduction des ligneux pour se reconstituer au cours du printemps 1986. La destruction des ligneux sous l'effet conjugué du triclopyr et du feu est satisfaisante sauf sur *Genista hispanica*. Toutefois, une part des 49% de 1987 est constitué de rejets de *Phillyrea latifolia* et d'*Acer monspessulanum* apparus à la suite du feu en 1986 et qui, de ce fait, n'ont pas été traités.

Le dispositif de Mazaugues86

Les principaux résultats sont regroupés sur la figure "Evolution relative du phytovolume de 1985 à 1988" où sont portées les évolutions des indices volumiques de la litière, des herbacées et des ligneux, observés sur des bandes de 20 m². Pour une lecture plus aisée des graphiques, les valeurs de l'indice portées pour les traitements de l'hiver 1985-1986 "feu" et "feu + glyphosate" correspondent aux mesures effectuées immédiatement après le brûlage, l'indice est donc nul, tandis que les valeurs retenues pour le calcul correspondent aux mesures effectuées avant la mise à feu.

Ceci permet de visualiser la reconstitution de la litière. Elle est rapide sur les parcelles où le feu puissant a occasionné des dommages foliaires importants, en particulier sur les pins dont les aiguilles sèches sont tombées dans les semaines qui ont suivies le brûlage dirigé. Par contre, elle est beaucoup plus lente sur les parcelles où le feu de faible puissance n'a occasionné que peu de dommages foliaires, la reconstitution s'effectue donc au rythme normal de la contribution annuelle. Enfin, elle se situe en position intermédiaire dans les parcelles ayant reçu le traitement "feu + glyphosate", les herbacées et le feuillage des ligneux détruits par la matière active tombent au sol et augmentent la quantité de litière durant l'année qui suit le traitement.

Ce même phénomène se produit sur les parcelles débroussaillées à la main. Malgré la qualité du travail réalisé par l'équipe de l'Office des Forêts, et en raison de la puissance des strates basses sur les parcelles débroussaillées, une partie des rémanents a été laissée sur le sol. Ceci a pour conséquence d'accroître significativement le phytovolume de la litière. Ce phénomène est encore plus net lorsque la végétation est broyée, le phytovolume peut être alors multiplié par 3 ou 4 (indices de 300 à 400). Cet inconvénient pourrait être évité par la combinaison **broyer et brûler**, le brûlage dirigé, après le broyage, élimine cette litière rémanente.

L'effet temporaire du feu sur la strate herbacée se matérialise par une reconstitution rapide du phytovolume, 60% au cours de la première année, plus de 75% au cours de la seconde et la cicatrisation complète du milieu au cours de la troisième. La courbe correspondante pour le débroussaillement montre un infléchissement temporaire, en réalité plus marqué que sur la figure, 75% du phytovolume initial sont reconstitués au cours de la première année et la totalité au cours de la seconde. Par contre, le glyphosate permet de maintenir le tapis herbacé à moins de 10% du phytovolume initial au cours de la première année, à moins de 25% au cours de la seconde et le tapis n'a récupéré que la moitié du phytovolume à l'issue de la troisième année, ceci est vrai qu'il soit appliqué seul ou après le brûlage.

Cette réussite ne doit toutefois pas occulter trois difficultés :
1) Le tapis d'herbacées, traité au glyphosate, sèche très rapidement (deux à trois semaines après le traitement) ; il constitue, dès la fin du printemps, un milieu particulièrement inflammable et combustible tout au long de l'été et il ne se résorbe qu'à partir de l'automne ; ceci rend le traitement au glyphosate seul peu compatible avec le rôle de la coupure de combustible.
2) Certaines espèces herbacées, comme *Molinia caerulea*, ont, en l'absence de traitement au glyphosate, profité au maximum de l'apport de potasse des cendres pour reconstituer un phytovolume supérieur au phytovolume initial dès la première année, certaines dicotylédones ont le même comportement.
3) Certaines espèces herbacées sont peu sensibles au glyphosate et profitent de l'absence de concurrence pour se développer, la mutation de flore peut conduire à l'apparition d'espèces très inflammables. Elle peut, toutefois, être bénéfique si des espèces comme *Aphyllanthes monspeliensis* envahissent la coupure, dans ce cas sa combustibilité décroît.

Sur les ligneux bas, les trois traitements conduisent à une réduction massive du phytovolume à l'issue de la première année. L'application de glyphosate sur de jeunes rejets permet de maintenir le phytovolume à la moitié du niveau de reconstitution observé sur le débroussaillement ou le brûlage dirigé. Ce retard devrait logiquement conduire à retarder le prochain passage en entretien et permettre sur dix ans de gagner un ou deux cycles.

Très satisfaisante lorsque les ligneux sont sensibles au glyphosate, la combinaison **brunir et brûler** peut conduire à une impasse lorsqu'ils le sont trop ou lorsqu'ils ne le sont pas. Dans le premier cas, en effet, la matière active ne migre pas dans le végétal elle est piégée dans le feuillage qui chute très vite au sol. Dans le second cas, la matière active pénètre et migre dans le végétal mais est sans effet. Dans les deux cas, l'appareil aérien détruit par le feu sera remplacé, dès la saison de végétation qui suit les traitements, par des rejets qui vont d'autant plus croître qu'ils vont profiter de la moindre concurrence des herbacées et de la fertilisation en potasse par les cendres. Enfin, lorsqu'un nouveau débroussaillement sera rendu nécessaire par la croissance active des rejets, le brûlage dirigé ne pourra être employé faute de tapis herbacé continu et dense, sauf si la strate arborée a reconstitué une litière suffisante pour permettre la propagation du feu. La solution envisageable consiste à opérer par étapes, à l'éradication des ligneux sans toucher à la strate herbacée, par application localisée de glyphosate ou traitement en plein de phytocides sélectifs des graminées puis application de la méthode **brunir et brûler** pour réduire les graminées ou de la méthode **brûler et brouter** si le pâturage est possible.

CONCLUSIONS

Les résultats exposés ci-dessus montrent combien il est nécessaire de raisonner l'entretien, voire la création, des coupures et plus particulièrement leur structure, en tenant compte des méthodes susceptibles d'être employées pour d'éviter d'aboutir à des impasses techniques et de condamner le gestionnaire à n'employer qu'une seule méthode.

Il se confirme que le feu est un outil très intéressant, parce qu'efficace et économique en hommes et en matériels, même si la linéarité des coupures et leur étroitesse ne permettent pas une optimalisation de ses possibilités. Par contre, sa mise en oeuvre demande que soient résolues les des deux questions suivantes, en terme d'organisation des chantiers :
* d'une année sur l'autre, les fluctuations climatiques de grande amplitude rendent impossible la planification de travaux à long terme, les brûlages ne peuvent être organisés que par les équipes de terrain elles-mêmes qui, au coup par coup, tiendront compte des conditions climatiques locales,
* la grande hétérogénéité de la végétation demande à ce qu'une typologie très précise des coupures soit réalisée au préalable, en veillant à définir malgré tout des unités de gestion d'une taille suffisante.

La combinaison du phytocide avec le débroussaillement, **brunir et broyer**, ou avec le feu, **brunir et brûler**, se justifie dès lors que l'éradication, la plus rapide possible, de certaines espèces des strates basses est désirée en raison de leur dynamisme et/ou de leur combustibilité. Pour réaliser ce traitement sélectif et localisé, il est indispensable de bien connaître les réactions des différents groupements végétaux selon la matière active, la dose et la période d'application pour prévoir les substitutions de flore, pour éviter celles qui seraient en contradiction avec l'objectif assigné aux coupures et, au contraire, pour favoriser celles qui leur permettront de jouer pleinement leur rôle préventif, touristique ou pastoral.

Les réactions des strates basses et de la strate arborée sont comparées en permanence à celles induites par le débroussaillement qui reste, malgré son coût, la technique de base de création et d'entretien des coupures.

Dans d'autres milieux que les coupures de combustible, cette comparaison n'a plus de sens. Des zones forestières ou des pâturages de montagne ne seront jamais entretenues par cette méthode en raison de son coût prohibitif et des difficultés techniques de mise en oeuvre (pente, enrochement, etc...). Le brûlage dirigé et la combinaison **brunir et brûler** doivent trouver leur place dans la gestion de ces espaces pour l'entretien desquels le propriétaire ne peut engager d'investissements trop lourds dont la rentabilisation est aléatoire. En effet, l'entretien de ces espaces ne se justifie que pour permettre le maintien ou pour aider à l'installation d'une population agro-pastorale qui équilibre son budget grâce au tourisme.

Sinon, ces milieux se refermeront, par embroussaillement généralisé, à moins que des incendies, d'autant plus dévastateurs que les discontinuités auront disparu, ne parcourent ces friches puis ne se communiquent aux forêts et ne détruisent les peuplements forestiers de protection, installés à grand frais depuis la fin du siècle dernier. Des études sont donc à poursuivre, tant sur les coupures de combustible qu'en dehors de celles-ci.

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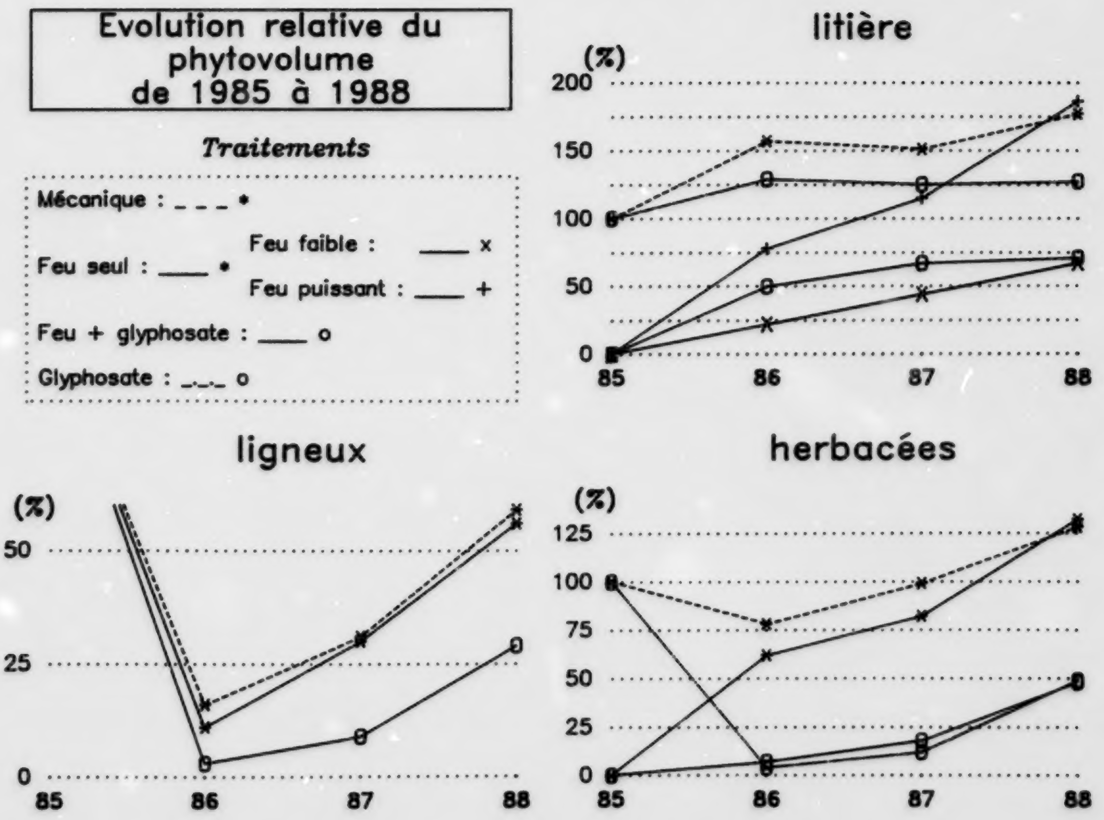

Evolution relative du phytovolume de 1985 à 1988
Traitements
Mécanique : _ _ _ *
Feu seul : ____ *
Feu faible : ____ x
Feu puissant : ____ +
Feu + glyphosate : ____ o
Glyphosate : _._._ o
litière
(%)
200
150
100
50
0
85
86
87
88
ligneux
(%)
50
25
0
85
86
87
88
herbacées
(%)
125
100
75
50
25
0
85
86
87
88

URBAN FORESTRY IN MALAYSIA - CURRENT AND FUTURE

Zakariya H. Abdullah

Lecturer in Urban Forestry
Department of Forest Management

Universiti Pertanian malaysia
43400 Serdang, Selangor, Malaysia

FDC : 270: 907: (595)

SUMMARY

Kuala Lumpur is blessed with the presence of many stretches of vegetation and open spaces both within and around its borders. While urban development has caused some of these areas to be converted for other uses, effects in greening of the cuts has shown some positive effects. Eventhough the current emphasis tends to be more on beautification, the present awareness on the importance of urban forestry has initiated various measures to ascertain that greenery should be planned, managed, and sustained not only for aesthetics, but functional purpose both for current and future needs.

INTRODUCTION

Kuala Lumpur (Lat. 3°08'N, Long. 101° 44'E), the capital city of Malaysia, lies in the heartland of the tropics. It was once the seat of one of the richest and oldest forests of the world. The city is unique as it still has many stretches of green vegetation in its domain, while in the outskirts are found extensive lowland and Hill Dipterocarp forests reserves almost encircling the city.

A birds-eye-view of the city will convey the panorama of greenery intermittenly broken up by juttings of modern sky scrapers, paved surfaces, and old shop-houses that give a distinct character of Kuala Lumpur. While urban tree planting is actively being carried out, other urban developments are threatening the city environmentally. As such, tree planting alone without any serious and long term approach may not be effective to create and sustain functional greenery for current and future needs.

BRIEF HISTORY OF THE CITY

The city grew from a tiny settlement of eighty inhabitants in 1857 to a few thousands in the early 1900s. Early tradings of tin and rubber attracted more settlers which gradually led to other economic and administrative activities that continously build up the population. By the mid-seventies the population exceeded half a million. As industries were developed, particularly when Kuala Lumpur was made the capital city, major urban activities began to pick up momentum which became the focal point of employment and business opportunities for the people. As such, by 1988 the city population catapulted to 1.2 million people. With the current rate of annual growth of four percent the capital city is expected to harbour two million people by the year 2000.

URBAN PROBLEMS

High population growth is always associated with myriads of common urban problems such as environmental pollution and degradation, pressure for landspace, traffic congestions, housing and health problems, poor urban drainage, and waste collection and disposal difficulty, and not the least of which is diminishing green areas.

Pollution Problems

An increase in the number of motor vehicles and industries in and around the city have resulted in air and water pollution. In a study of the city pollution, Mohd and Badri (1988) recorded the occurence of high level of heavy metals especially lead in the soils and dust. They were noted in excess of standard allowable quantities. Other aspects of urban pollutions have also been extensively studies by the local researches resulting in various measures taken by the Ministry of Environments to curb the problems.

As the population grows, especially with an increase in affluence on one hand, and the concurrent growth of squatters on the other, problems of refuse collection and disposal arise. Of the current daily refuse of 5000 tons, only 2000 tons are handled by the city hall, while the remainder is left unattended due to poor access (Dato' Elias 1988). The volume is expected to double by the year 2000.

Demand For Land Space

Clamoring for space is a common phenomenon for a growing city. High demand for land especially in commercial areas has escalated property values. Since essentially most city land has potential for fetching good prices, retention of spaces for conservation purposes often face with the

problems of stiff competition from other land uses which can yield apparent financial benefits. Only gazetting of areas for conservation by legislative means may temporarily sustain the green areas for environmental, asthetic and other socially beneficial purposes.

While Teh (1989) stated that at least 45 percent of land area in the capital city could be classified under green space in his mapping project, Zakariya and Jeffri (1989) questioned the quality of the urban greenery in terms of structure and diversity. The Kuala Lumpur structural plan (1984) indicated that nearly half of the total land area was taken up by the existing built-up area as indicated in Table 1. Every indication is that the trend is always on the rise as a fairly large portion of the land has been approved for development.

Table 1: Available Land in the Federal Territory

Use of land	Area (Ha)	Percent
Existing built-up	10,938	44.9
Approved development	4,765	19.5
Special projects	1,298	5.3
Active mining	1,462	6.0
Land above 122 meter	748	3.1
Land available	3,920	16.1
Total	24,364	100

Source: Kuala Lumpur Structural Plan 1984.

Among the vegetation areas of the city that gave way to the rapid housing development of the seventies were the scattered secondary forest land, old rubber and oil palm plantations, the extensive tin tailings sites and many other unused open spaces that had great potential for greenery. Sham (1982) attributed the increasing occurence of flash floods in the city specially during rainy seasons as the result of removal of vegetation with the replacement of built-up surfaces. It is a well-known fact that built-up surfaces not only impede water infiltration into the soil, but also help to expedite water collection and swelling of drainage systems within a short span of time. Disturbance of the forests and other development activities in the upstreams of the city have also contributed to heavy siltation of the rivers that pass through Kuala Lumpur.

CURRENT STATUS

The City Hall has embarked on an active urban tree planting and park establishment programme to meet the pressing social and environmental needs

of the urbanites. Prior to the current awareness on the urgent needs of urban greenery three areas have long been gazetted as forest reserves in the city (Table 2).

Table 2: Gazetted Forest Reserves

The Forest Reserves	Area (ha)	Year gazetted
1. Bukit Nanas	11.05	1906
2. Bukit Sg. Puteh	36	1923
3. Bukit Sg. Besi	42.1	-

Of the three gazetted forest reserves, only the Bukit Nanas contains some remnants of indigenous lowland Dipterocarp species through partly being encroached by the secondary species. Only 8.9 hectares of the Bukit Sg. Puteh forest reserve is in the Federal Territory, while the remainder is in the state of Selangor. However, both the Bukit Sg. Puteh, and the Bukit Sg. Besi forest reserve have been completely disturbed, and no trace of the indigenous forest species are found. They are therefore classified as secondary forests (Zakariya and Ainuddin 1990).

In addition to the gazetted forest reserves several more areas have been developed for public parks. They include:

1.	Taman Tasik Perdana	101 ha
2.	Taman Tasik Titiwangsa	52.6 ha
3.	Taman Bandar Tun Razak	49 ha
4.	Taman Tunku Abdul Rahman	11 ha
5.	Danau Desa	73 ha

In areas where the secondary vegetation have been fairly advance with the presence of many big trees, they have been designated as urban nature reserves. Kavanagh et al. (1988) recommended the establishment of bird corridors linking identified bird reservoirs with the vegetation areas of Kuala Lumpur to parklands in the proposals for a conservation strategy for the Federal Teritory of Kuala Lumpur.

Urban Tree Planting

A serious effort of urban tree planting began in 1973 as a result of an awareness of the environmental deteriorations by the authority. The Kuala Lumpur structural plan which came into effect in 1984 emphasizes on the concept and direction of urban tree planting which includes the followings:

1. Planting of shade trees
2. Establishement of theme gardens

3. Beautification and ornamental plantings
4. Slope planting
5. Roadside planting and beautification, and
6. Ground covers

The tree planting program has obviously shown good result as evidenced by the positive response of the city inhabitants and tourists. Infact, returning visitors who have been to the city a few years before were very impressed by the improvement.

The hostings of the ASEAN games and the CHOGM meeting in Kuala Lumpur in the later part of 1989 resulted in an unprecedented allotment of budget for urban beautification. The effort was further enhanced by the preparation for the visit Malaysia Year 1990 kick off which began shortly after. Khuzaimah (1989) mentioned that up to September of 1989 a total of 257,440 trees have been planted giving an average annual rate of 15,000 trees. The city record indicates a total of 278 species of trees planted with the ten most common ones being:

1. Pterocarpus indicus
2. Lagestroemia speciosa
3. Ficus benjamina
4. Cinnamomum iners
5. Swientenia macrophylla
6. Delonix regia
7. Samanea saman
8. Mimusop elengi
9. Millettia atropurpurea
10. Peltophorum pterocarpum

In an earlier survey of six major tree planting areas of Kuala Lumpur and the neighbouring satelite city of Petaling Jaya, Zakariya and Jeffri (1989) recorded 121 species of shade trees from 38 families. Each study area namely the residential site, recreational parks and the golf course contained between 60 - 77 species with nearly equal portion of the native and exotic species.

Ang (1986) surveyed two natural vegetation sites of the city, namely an established secondary stand near Kenny Hill, and a remnant forest reserves of Bukit Nanas which is located in the middle of the city. In the former a total of 52 species of trees and plants were recoreded, while in the latter 78 species of trees and plants were observed. Both areas contained various life forms including trees, palms, herbaceous plants, lianas, and ferns. Observations indicate that secondary forests of various sizes and phases occur in abundance all over the city.

In a serious attempt on conservation, the federal government has designated 607 ha. of old rubber plantation at Bukit Kiara bodering the city and Petaling Jaya township for an establishment of a park cum arboretum, of which about 113 ha. is for a public government course. Quah (1983) stated that 4000 species of native Malaysian plants would be planted to potray a good representation of the native flora. However due to some constraints the developments has been rather slow.

THE FUTURE OF URBAN FORESTRY

The seriousness of the Malaysian government on development and improvement of urban greenery especially Kuala Lumpur should be given credit. The progress and performance of beautification of the capital city have encouraged our towns in Malaysia to take similar steps of urban beautification. The objective of making Kuala Lumpur a garden city has almost been materialized especially with the country's concern of attracting tourism through enhancement of natural landscapes including urban parks and other green areas.

In addition to many parks that have been established many more are earmarked for establishment. They include:-

1.	Taman Pudu Ulu	-	55 ha
2.	Taman Wangsa Maju	-	27 ha
3.	Taman Sungai Batu	-	46 ha
4.	Taman Jinjang	-	59 ha
5.	Taman Sungai Midah	-	17.5 ha
6.	Taman Bukit Jalil	-	-
7.	Taman Kg. Pasir/Wardieburn	-	-

The city is surrounded by many rich and extensive forest reserves which are under the administration of the state of Selangor. Some of them extend even up to the mountainous areas which cover various types of ecosystems.

Zakariya (1987) recommended an establishment of a second zone urban forest system within certain kilometer radius from the city as a backup zone of green lung and multipurpose forests for parks, outdoor recreation, and wildlife reserves. He also outlined a various acquisition and management options that the city authority could coordinate with the state government. Kavanagh et al. (1988) also mentioned the need for the city to take measures of ascertaining that those forests that are located upstream be managed and conserved so as to alleviate flood problems that frequently occur in the country during rainy season.

In order to reduce the further occurence of environmental degradation from urban development, Environmental Impact Assessment should be carried out especially for the development of environmentally sensitive areas since provision has been made in the Environmental quality act of 1987.

Efforts should also be made to emphasise development of greenery in a broader sense within the framework of urban forestry as the current trend tends to be more of beautification work only. Enrichment planting with indigenous forest species have been suggested by Zakariya and Ainuddin (1989) in selected secondary vegetation areas so as to bring back the identity of the forest in the city. They also suggested gazetting of more urban green areas for parks and nature reserves.

The current administrative structure and strength at the park and garden department of the City Hall is inadequate to meet the need of urban forestry development. More foresters, ecologists and personnels of relevant fields need to be employed to make planning and implementation

effective. Liason with the forest department, especially with its newly formed urban forest unit should be expedited. To this effect, the forest department should also increase the strength of its urban forestry unit as to pave way for urban forestry development in Malaysia as a whole.

CONCLUSION

Awareness on the importance of urban greenery in all aspects is felt both by the public and administrators in Malaysia, particularly in the capital city. What was once taught of as near impossible has been proved wrong with a gradual but continuous positive change of the city landscapes. The concept and objective of making Kuala Lumpur a garden city have been achieved in slightly, more than a decade.

Greenery for asthetics alone is not enough. Vegetation, both natural and planted should be developed and managed to give maximum advantage to the city. This could only be realised through the concept of urban forestry which makes greenery not only asthetics but functional for environmental, social and economic purposes.

Kuala Lumpur is in an ideal situation to practice urban forestry as it still has many forested areas and open spaces within its domain, and also with the existence of extensive forest reserves in the outskirts. The time is now, as delay means more loss of potential green areas to other non-green landuse.

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SELECTION OF TREE SPECIES FOR URBAN PLANTINGS IN TROPICAL CITIES

C.Y. Jim

Lecturer in Biogeography and Soil Science
Department of Geography and Geology

University of Hong Kong
Pokfulam Road, Hong Kong

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SUMMARY

The selection of tree species for urban amenity plantings in the tropics should depart from subjective and irrational approaches. The necessary steps to reach a species selection decision are summarized in a synoptic figure. The large number of candidate species require a comprehensive and systematic evaluation. Results from detailed urban tree surveys are augmented by information gleaned from an extensive literature review and cursory tree examinations in 10 tropical cities. A matrix of 164 species by 24 amenity attributes has been compiled as a broad guide to tree selection.

Keywords: Amenity trees, species selection, tropical cities

INTRODUCTION

Tree planting for amenity uses, whether consciously or subconsciously practised, can be regarded as an integral part of many human cultures. The insertion of trees in built-up areas, a European landscape fashion that originated in the eighteenth century (Lawrence 1988), brought formal urban planting programmes to many colonial cities of the tropics. The fine tradition has been assiduously sustained in some places but sadly neglected in others. The gradual rise in affluence and environmental awareness in some parts of the Third World has accentuated the higher-level human need for a pleasant living milieu. Tree planting in human settlements is an effective way to upgrade the quality of life.

The humid tropics, rich in botanical heritage, provides numerous candidates for possible amenity purpose. Through centuries of trial and error, a varied assemblage of several hundred species have been adopted for landscape plantings. Whereas some have spread widely and become renowned pantropical ornamental trees, others including many worthwhile species remain rather obscure. The lack of scientific evaluation and effective communication certainly do not help. Moreover, the selection of species for urban forestry programmes, without adequate information and guidelines, often becomes an exercise of uncertainties if not guesstimates. There is thus a common tendency for subjectivity and inertia to entrench, resulting in persistent adherence to a small set of familiar, safe and "easy" species.

Such a state of affair contrasts pronouncedly with that in the temperate region where tree information, accumulated over many years of detailed scientific studies, is readily available. It therefore makes sense to summarize the existing data on tropical amenity trees, and use them as a preliminary species-selection guide and as the platform to formulate appropriate research endeavours. This paper aims at compiling such a list of systematic and comprehensive information especially geared towards urban plantings in the humid tropics.

SPECIES EVALUATION

Tree selection is based on species evaluation which can be accomplished by two different approaches. The experimental method involves long-term trial planting on permanent plots in an arboretum or research station (Chapin and Kozel 1975). The experimental design can isolate the effects under investigation through detailed observation and measurement of performance characteristics. The field method acquires data by a survey of representative tree samples in real-world situations (Gerhold 1985). Useful results can be obtained quickly and relatively cheaply, but the studies are confined to species that have already been adopted. A variant strategy is to test new species directly in field situations, taking into account the attendant vicissitudes. Due to the shortage of research resources for the studies on amenity trees, the field-survey method is deemed appropriate for the tropics.

Information for this paper is gleaned from a number of sources. Detailed surveys of trees in urban Hong Kong provide the primary data (Jim 1986a, 1986b, 198[illegible], 1990s). Since the founding of the city in 1840s, a large number of exotic plants have been introduced. At present, about three quarters of the 160 odd amenity species are aliens, most of which have adapted well to the local environment. The frequent movement of people, including British military personnel and civil servants, traders and missionaries, brought in a continuous stream of ideas and materials. Overall, about half of the exotic species originated from Tropical Asia, and the rest from Australia, Tropical America and the Far East (Jim 1990b). A small-scale tree survey in a county town in South China (Jim 1990c) provides supplementary information.

Secondary information is gathered through an extensive literature review of botanical, forestry, horticultural and arboricultural publications of Australia, India, Sri Lanka, Malaysia, Singapore, the Philippines, Fiji, the United States, and China. The 140 odd items of references have not been listed here. The vast collection of data was screened, compared and collated with the survey findings. Cursory field examinations of tree conditions 10 tropical cities furnish additional insights.

SPECIES SELECTION

Tree selection in the tropics is complicated by the large pool of actual and potential candidates. That it affords much latitude in choice is a blessing; the bewildering array is an onus. Unscientific and irrational tree selection should be substituted by logical and systematic decisions. There is a strong case to expand the repertoire outside the narrow range of popular species. To arrive at an optimal tree selection, a series of steps and considerations should be realized, a summary of which is given in Figure 1. Careful evaluations of habitat characteristics and landscaping objectives, equipped with the requisite tree knowledge, management capabilities and the availability of planting materials, are necessary preludes to a rational decision on species selection.

Detailed amenity attributes of 164 species have been condensed in a two-dimensional tree matrix (Table 1). The trees are listed under three life-form categories, namely 133 broadleaf, 22 palms and palm-likes and 19 conifers (except *Ginkgo biloba*). About four-fifths of the listed species are known to most tropical countries, and the remaining are mainly cultivated in Hong Kong and South China. The latter include the species with suitable amenity characters that deserve recommendation for trial in other areas. The information on the infrequently planted species may need clarifications and amendments in the light of more detailed evaluations. The information on final dimensions, growth rate, phenological changes and special morphological expressions may vary according to local environmental conditions.

The 24 attributes considered as the key criteria in species selection have been divided into five groups. It may be a truism to state that *tree dimensions* should match that of the growth space. Unfortunately, many trees have been planted in earnest without due regard to their considerable final dimensions. Such myopic neglect of long-term tree prospect is apparently rather prevalent. Physical confinement and the ancillary retarded and contorted growth as well as the necessary drastic excisions (often unskilfully if not improperly performed) routinely incur massive injuries and decline in tree health and vigour. The unsightly and incongruous "eyesores" often degenerate into heavy management burdens and potential hazards. The need to anticipate the available growth space especially in landscape planning for developing sites cannot be more strongly emphasized. A more sympathetic and enlightened attitude towards trees should be adopted by municipal and planning authorities.

Rapid growth and establishment is an attribute of much appeal for the prompt greening effects and quick escape from the vulnerable young years. The *interesting tree form* is an umbrella variable incorporating a tree architecture (notably crown geometry and branching habit) that deviates from a notional average form of tropical broadleaf trees, and can provide unusual sight or contrast to the landscape. The *deciduous habit* is welcomed as a reminder of the seasonal rhythm which is often indistinctly defined in the more humid parts of the tropics. The importance of *showy flowers, fined-textured or handsome foliage*, and *good shading effect* needs no further elaboration. The *seasonal foliage colour change* furnishes accents to the cyclic marches of nature, whereas *non-green* leaf colour provides a vivid contrast to the predominant green hue. *Hardiness and longevity*, and *nitrogen fixing* attributes allow trees to thrive in the stressful built-up areas.

The undesirable traits are not insurmountable management liabilities. They can be circumvented by proper site selection or corrective arboricultural treatments. For instance, trees with *shrubby habit* or *low crown base* can be planted away from pedestrian or vehicular traffic, or modified by branch training when they are still young, or corrected by crown lifting procedures. Similarly, an *untidy crown* can be trimmed by skilfull pruning. The hazards of *fragile branches* can be reduced by branch training, tree surgery, cabling and bracing. Trees with *buttress roots*, or *swollen trunk base* which could break and lift pavings should be planted only in sites with adequate open soils. The same precautions also apply to species with *aggressive shallow roots*.

The tags on *air pollution* tolerance do not differentiate between different types of gaseous and particulate pollutants. Such information is available only to a small number of popular species. Trees that can withstand *wet or poorly-drained sites* are well suited to low-lying areas and riverbanks, and soils with internal drainage impediments (such as heavy texture and the presence of slowly permeable pans). The ability to survive *strong winds* is undoubtedly an advantage in areas inflicted by tropical cyclones and in open exposed sites.

Lastly, the hints on suitable habitats denote a synthesis of the above amenity traits. Whereas all trees can be grown in *gardens and open spaces* with little constraints, some are unsuitable to *pavement or roadside habitats* due to final dimensions and potential hazards. Species for *hillslopes* can tolerate thin, skeletal, unstable and poor soils, exposure. Salt-spray endurance allows trees to be inserted at *coastal sites*, whereas the additional abilities to live in an unstable and infertile sandy substrate intruded by salt water permit planting on *sandy beaches*.

CONCLUSIONS

Tree selection is the fundamental if not pivotal decision in a series of amenity planting procedures. The correct choice of a species for a landscape site depends on wide spectrum of criteria ranging from objective-scientific to subjective-aesthetic. The crucial consideration, besides the important decorative and visual impacts, is the survival and general well-being of the trees in the often stressful unnatural habitats associated with human settlements. A properly selected tree in terms of species, quality (due to genetic superiority) and nursery treatments will thrive in the landscape and be free from troubles.

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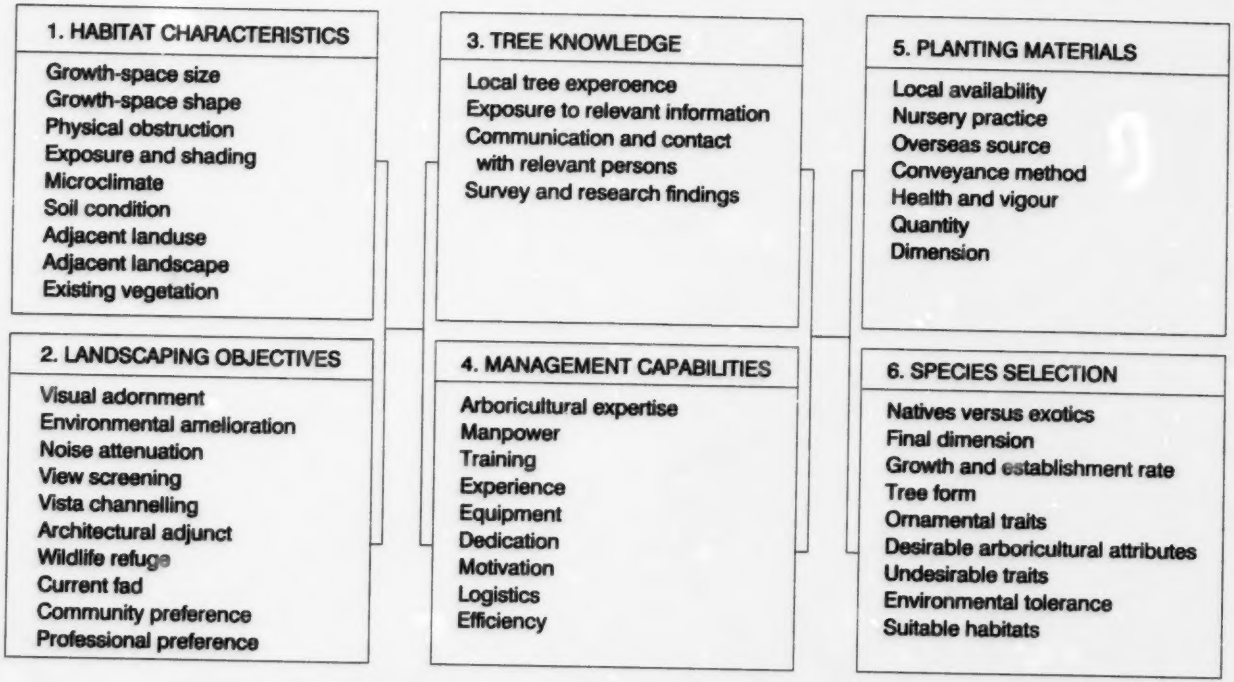

Figure 1 : Summary of steps and considerations leading to the decision in amenity-tree selection

Table 1: Characteristics of amenity-tree species suitable for the humid tropics

Species	Common name	Family	Amenity attributes*
A. BROADLEAF			A B C D E F G H I J K L M N O P Q R S T U V W X
Acacia auriculiformis	Ear-pod wattle	Mimosaceae	C G J K P Q R S T U V
Acacia confusa	Acacia	Mimosaceae	C G J K L P Q S U V
Acacia mangium	Mangium	Mimosaceae	C I J P R S U V
Ailanthus fordii	Ailanthus	Simarubaceae	C D G Q S T U V
Albizia lebbeck	Lebbeck tree	Mimosaceae	C E G H I K S T U V W
Aleurites moluccana	Candlenut tree	Euphorbiaceae	C I N P Q T U
Aleurites montana	Wood-oil tree	Euphorbiaceae	C I N T U V
Artocarpus altilis	Breadfruit	Moraceae	B C G I M Q U V
Bauhinia blakeana	Hong Kong orchid tree	Caesalpiniaceae	C F K M N T U
Bauhinia purpurea	Purple camel's foot	Caesalpiniaceae	C E F K L M N T U
Bauhinia tomentosa	Yellow-flower bauhinia	Caesalpiniaceae	F G K L U
Bauhinia variegata	Camel's foot	Caesalpiniaceae	C E F K L M N Q T U
Bischofia javanica	Autumn maple	Euphorbiaceae	A B C E F G H I L Q R S T U V
Bombax malabaricum	Red kapok tree	Bombacaceae	A C D E F G N O P Q T U W
Brachychiton acerifolium	Flame bottle tree	Sterculiaceae	C D E F G N T U
Broussonetia papyrifera	Paper mulberry	Moraceae	C E J L M Q S T U V
Callistemon rigidus	Stiff bottle-brush	Myrtaceae	C F M T U V W
Callistemon viminalis	Tall bottle-brush	Myrtaceae	C D F L R T U V
Camellia crapnelliana	Crapnell's camellia	Theaceae	D F U V
Carica papaya	Papaya	Caricaceae	C D G U V
Cassia fistula	Golden shower	Caesalpiniaceae	C E F G K T U
Cassia javanica	Pink shower	Caesalpiniaceae	C E F G I L T U
Cassia nodosa	Pink and white shower	Caesalpiniaceae	C E F G I L T U
Cassia siamea	Kassod tree	Caesalpiniaceae	A C F I J M Q S T U V W

Cassia spectabilis	Spectacular cassia	Caesalpiniaceae	C F G K M T U
Cassia surattensis	Sunshine tree	Caesalpiniaceae	C F G K M Q T U W
Castanopsis fissa	Chestnut oak	Fagaceae	C F I J M U V
Casuarina equisetifolia	Horsetail tree	Casuarinaceae	A C D G J K O P Q S T U V W X
Casuarina stricta	Drooping she-oak	Casuarinaceae	C D G J K O P Q S T U V W
Ceiba pentandra	Silk cotton tree	Bombacaceae	A B C D E F G O P U V
Celtis sinensis	Chinese hackberry	Ulmaceae	A B E H I J P Q S T U V W
Cerbera manghas	Sea mango	Apocynaceae	C F J L S U W X
Choerospondias axillaris	Hog plum	Anacardiaceae	A B C D E I Q T U V
Chorisia speciosa	Floss-silk tree	Bombacaceae	C D F G T U
Cinnamomum burmanii	Cinnamon tree	Lauraceae	I T U V
Cinnamomum camphora	Camphor tree	Lauraceae	A B C H I J P Q S T U V W
Citrus grandis	Pomelo	Rutaceae	L Q U V
Citrus reticulata	Tangerine	Rutaceae	L Q U V
Clausena lansium	Wampi	Rutaceae	M T U
Cleistocalyx operculata	Water banyan	Myrtaceae	I J R U
Crateva religiosa	Spider tree	Capparidaceae	C D F G H I Q S T U V
Cratoxylum ligustrinum	Yellow-cow wood	Hypericaceae	D J S T U V
Dalbergia balansae	South China rosewood	Papilionaceae	C E F K M T U V
Delonix regia	Flame of the forest	Caesalpiniaceae	A B C D E F G H I K N O P Q T U V W
Dillenia indica	Elephant apple	Dilleniaceae	C G I S T U
Dimocarpus longan	Longan	Sapindaceae	C I T U
Dracontomelon dao	Yanmin	Anacardiaceae	A O P U V
Elaeocarpus hainanensis	Hainan elaeocarpus	Elaeocarpaceae	C D L M R U V
Erythrina corallodendron	Coralbean tree	Papilionaceae	C E F G J K L M S U
Erythrina crista-galli	Cockspur coral	Papilionaceae	D E F J K L M U
Erythrina speciosa	Common coral tree	Papilionaceae	C E F G K M R T U
Erythrina variegata	Indian coral tree	Papilionaceae	C E F G K M N R T U V W
Eucalyptus citriodora	Lemon-scented gum	Myrtaceae	A C D P S T U V W
Eucalyptus grandis	Rose gum	Myrtaceae	A C D U V W

Eucalyptus robusta	Swamp mahogany	Myrtaceae	A C D Q R T U V W
Eucalyptus saligna	Sydney blue gum	Myrtaceae	A C D U V
Eucalyptus tereticornis	Forest gray gum	Myrtaceae	A C D T U V
Eucalyptus torelliana	Cadaga	Myrtaceae	A C D S U V W
Euphorbia cotinifolia	Red euphorbia	Euphorbiaceae	C H L U
Euphorbia pulcherrima	Poinsettia	Euphorbiaceae	C F L U
Ficus benjamina	Weeping fig	Moraceae	A B C D I J P U
Ficus elastica	Indian rubber tree	Moraceae	A B C G I J M O P U V W X
Ficus lyrata	Fiddle-leaf fig	Moraceae	C G L M U V
Ficus microcarpa	Chinese banyan	Moraceae	A B D I J O P Q S T U V W
Ficus religiosa	Peepul tree	Moraceae	A B C E G H M T U V W
Ficus rumphii	Mock peepul tree	Moraceae	A B C E G H M T U V
Ficus superba	Superb fig	Moraceae	I J T U V
Ficus variegata	Red-stem fig	Moraceae	A E J O Q T U V
Ficus virens	Large-leaf banyan	Moraceae	E H I J O P S T U V
Firmiana simplex	Chinese parasol tree	Sterculiaceae	C D E I Q T U V
Garcinia spicata	Common garcinia	Guttiferae	D G Q S U
Grevillea banksii	Bank's grevillea	Proteaceae	F G M U
Grevillea robusta	Silk oak	Proteaceae	A C F G T U W
Hibiscus tiliaceus	Sea hibiscus	Malvaceae	C F I Q S T U W X
Ilex rotunda	Chinese holly	Aquifoliaceae	F I T U
Jacaranda mimosifolia	Jacaranda	Bignoniaceae	E F G T U
Lagerstroemia speciosa	Queen crape-myrtle	Lythraceae	E F H M Q S T U
Leucaena leucocephala	White popinac	Mimosaceae	C G J K L M S U V W
Ligustrum lucidum	Glossy privet	Oleaceae	C I Q T U
Liquidambar formosana	Sweet gum	Hamamelidaceae	A C E G H I Q S T U V
Litchi chinensis	Lychee	Sapindaceae	I R S T U V
Litsea glutinosa	Pond spice	Lauraceae	I J S T U V W
Litsea monopetala	Persimmon-leaf litsea	Lauraceae	I T U
Macaranga tanarius	Elephant's ear	Euphorbiaceae	C D G I L S T U V W X

Machilus chinensis	Chinese machilus	Lauraceae	H	T U V
Machilus thunbergii	Red machilus	Lauraceae	H	S T U V
Magnolia grandiflora	Lotus-flower magnolia	Magnoliaceae	C F	Q S U V
Mallotus paniculatus	Turn-in-the-wind	Euphorbiaceae	C D G	U V
Mangifera indica	Mango	Anacardiaceae	A B C H I J	Q T U
Mangifera persiciformis	Flat mango	Anacardiaceae	A B C I	Q T U V
Manilkara achras	Sapodilla	Sapotaceae	M	S U
Melaleuca leucadendron	Paper-bark tree	Myrtaceae	C D F	Q R S T U W
Melia azedarach	Persian lilac	Meliaceae	C E F G J	Q T U V W X
Michelia alba	White champak	Magnoliaceae	A C F	T U
Michelia champaka	Yellow champak	Magnoliaceae	C F	T U
Mimosops elengi	Spanish cherry	Sapotaceae	I	T U
Morus alba	White mulberry	Moraceae	L	Q S U V W
Nerium indicum	Oleander	Apocynaceae	F J L	Q S T U V
Paulownia fortunei	Foxglove tree	Scrophulariaceae	A C D E F	Q T U V
Peltophorum pterocarpum	Yellow poinciana	Caesalpiniaceae	A C E F G I K	S T U W
Platanus acerifolia	London plane	Platanaceae	A B C E	P Q T U
Plumeria acutifolia	Common fragipani	Apocynaceae	C E F L	U
Plumeria rubra	Red fragipani	Apocynaceae	C E F L	U
Polyalthia longifolia	Mast tree	Annoniaceae	D G	T U
Polyscias guilfoylei	Guilfoyle polyscias	Araliaceae	G L	U
Pongamia pinnata	Wild bean	Papilionaceae	C F I	S T U W X
Populus nigra var Italica	Lombardy poplar	Salicaceae	A C D E G	P R S T U W
Prunus mume	Flowering plum	Rosaceae	F L	U V
Prunus persica	Flowering peach	Rosaceae	F L	U V
Psidium guajava	Guava	Myrtaceae	C F J M	U V
Pterocarpus indicus	Burmese redwood	Papilionaceae	A B C E F I K	S T U W
Punica granatum	Pomegranate	Punicaceae	E F G L	Q U V
Rhodoleia championi	Silk rose	Hamamelidaceae	F I	U V
Salix babylonica	Weeping willow	Salicaceae	C D G	Q R T U

Samanea saman	Rain tree	Mimosaceae	A B C D E F G I	U V
Sapindus mukorossi	Soap berry	Sapindaceae	D E	S T U
Sapium sebiferum	Tallow tree	Euphorbiaceae	C E G H	Q S T U V W
Schefflera actinophylla	Umbrella tree	Araliaceae	C D G L	T U
Schefflera octophylla	Ivy tree	Araliaceae	C I J	T U V
Spathodea campanulata	African tulip tree	Bignoniaceae	C F M	U V
Sterculia lanceolata	Scarlet sterculia	Sterculiaceae	F I	T U V
Swietenia mahogani	West Indies mahogany	Meliaceae	B E I	S T U V W
Syzygium cumini	Jambolan plum	Myrtaceae	A B C I	S T U V
Syzygium grande	Sea apple	Myrtaceae	A B C F	S T U W X
Syzygium jambos	Rose apple	Myrtaceae	F I	R S T U
Syzygium samarangense	Java apple	Myrtaceae	F	T U
Tectona grandis	Teak	Verbenaceae	A C E	T U V
Terminalia catappa	Indian almond	Combretaceae	A B C D E G H	Q R S T U W X
Thespesia populnea	Portia tree	Malvaceae	C F G	R T U W X
Thevetia peruviana	Yellow oleander	Apocynaceae	F G L	Q S T U V
Toona sinensis	Chinese mahogany	Meliaceae	A C	R T U V
Tristania conferta	Brisbane box	Myrtaceae	A C I J	T U V W
Viburnum odoratissimum	Sweet viburnum	Caprifoliaceae	B	Q U

B. PALMS AND PALM-LIKES

Alsophila spinulosa	Spiny tree fern	Cyatheaceae	C D	R U V
Archontophoenix alexandrae	King palm	Palmae	A D	R T U V W
Caryota ochlandra	Fish-tail palm	Palmae	C D	U
Chrysalidocarpus lutescens	Bamboo palm	Palmae	D	Q S U
Cocos nucifera	Coconut palm	Palmae	A D	Q R S T U W X
Cycas revoluta	Cycad	Cycadaceae	D J	Q S U
Hyophorbe lagenicaulis	Bottle palm	Palmae	D	Q S U W
Hyophorbe verschaffeltii	Spindle palm	Palmae	D	Q S U W
Livistona chinensis	Chinere fan palm	Palmae	D J	Q R S T U V W

Musa paradisiaca	Banana	Musaceae		C	D											U	V		
Neodypsis decaryi	Triangular palm	Palmae			D									S		U			
Phoenix canariensis	Canary Island date palm	Palmae			D										T	U			
Phoenix dactylifera	Date palm	Palmae			D			J						S		U		W	
Phoenix hanceana	Spiny date palm	Palmae			D											U	V		
Phoenix roebelenii	Dwarf date palm	Palmae			D									S	T	U		W	
Ptychosperma macarthurii	Macarthur palm	Palmae		C	D								R			U	V		
Ravenala madagascariensis	Traveller's tree	Strelitziaceae			D											U			
Roystonea regia	Royal palm	Palmae		C	D			J				Q	R	S	T	U		W	
Strelitzia nicolae	Strelitzia	Strelitziaceae			D											U			
Syagrus romanzoffiana	Queen palm	Palmae		C	D								R		T	U		W	
Trachycarpus fortunei	Windmill palm	Palmae			D			J				Q			T	U	V	W	
Washingtonea robusta	Petticoat palm	Palmae			D			J				Q	R	S	T	U		W	

C. CONIFERS

Agathis robusta	Kauri pine	Araucariaceae	A		D									S		U			
Araucaria bidwillii	Bunya-bunya	Araucariaceae	A	C	D		G							S		U		W	
Araucaria cunninghamii	Hoop pine	Araucariaceae	A		D		G					Q		S	T	U		W	
Araucaria heterophylla	Norfolk Island pine	Araucariaceae	A		D		G					Q		S	T	U		W	X
Callitris robusta	Cypress pine	Cupressaceae		C	D				L							U			
Chamaecyparis pisifera	Yellow sawara cypress	Cupressaceae	A		D		G									U			
Cryptomeria japonica	Peacock pine	Taxodiaceae	A	C	D		G	J						S	T	U		W	
Cunninghamia lanceolata	Chinese fir	Taxodiaceae	A	C	D		G	J								U	V		
Ginkgo biloba	Maiden-hair tree	Ginkgoaceae	A		D	E	G	J				Q		S	T	U			
Glyptostrobus pensilis	Water pine	Taxodiaceae			D	E	G						R	S	T	U			
Juniperus chinensis	Chinese juniper	Cupressaceae			D		G	J	L			Q				U	V	W	
Metasequoia glyptostroboides	Dawn redwood	Taxodiaceae	A	C	D	E	G	J			O		R		T	U			
Pinus elliottii	Slash pine	Pinaceae	A	C	D								R	S		U	V	W	
Pinus massoniana	Chinese red pine	Pinaceae	A	C	D			J						S		U	V		
Podocarpus macrophyllus	Buddhist pine	Podocarpaceae			D		G	J		M		Q		S		U	V	W	

Podocarpus nagi	Nagi	Podocarpaceae	D G U
Podocarpus neriifolius	Thitmin	Podocarpaceae	A D G U
Taxodium distichum	Bald cypress	Taxodiaceae	A C D E G J R S T U W
Thuja orientalis	Oriental arbor-vitae	Cupressaceae	D G J L Q U V

*Notations for amenity attributes:

Tree dimensions
- (A) Usual final height >20 m
- (B) Usual final crown spread >8 m

Desirable traits
- (C) Fast growth and establishment
- (D) Interesting tree form
- (E) Deciduous habit
- (F) Showy flowers
- (G) Fine-textured or handsome foliage
- (H) Seasonal foliage colour change or non-green leaf colour
- (I) Good shading effect
- (J) Hardiness or longevity
- (K) Nitrogen fixing

Undesirable traits
- (L) Shrubby habit or low crown base
- (M) Untidy crown
- (N) Fragile branches
- (O) Buttress roots or swollen trunk base
- (P) Shallow or aggressive roots

Environmental tolerance
- (Q) Air-pollution
- (R) Wet or poorly-drained sites
- (S) Strong wind

Recommended habitats
- (T) Pavement or roadside habitats
- (U) Gardens and open spaces
- (V) Hillslopes
- (W) Coastal sites
- (X) Sandy beaches

N U E V O A N A L I S I S C I E N T I F I C O P A R A L O S E S P A C I O S V E R D E S D E L A S M O D E R N A S C I U D A D E S

Enrique Oswaldo Videla Pilasi
Biogeocenologia Forestal

Jardin Botánico
Santisima Trinidad, Asunción, Paraguay

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SUMMARY

This contribution clarifys the actual concern as shown by the forestry purposes from the creating efforts in building up commercial forest plantations to the requierements upon the profiles to be accomplished in laying out green spaces in the modern cities. Coloured-pictures (slides) justly described,perform an Appendix within this contribution.New developments in Urban Forestry could be promoted from them. "Landscapes Building Planning", is in our Era, the subject in priority services for the nations survival.New reciprocal equation (Feedbacks) by the author is outlined.

Keywords: Greening-Education; Hyperspace-meaning;Conserving -biodiversity;Biogeocenology;Biometeorology.

INTRODUCCION

Las palabras claves son el escenario explicativo para quienes desean ubicarse en la primera fila y entender este tema crucial: LA VIDA GLOBAL EN LAS MODERNAS CIUDADES.

Las modernas ciudades deben concebirse y planificarse como "UN TECHO PARA CRECER".

Por ello el árbol tiene en este espacio critico(Hiperespacio) un protagonista de la "cuarta dimensión"(El ambiente de la Perpetuidad)(Videla Pilasi 1989)

Para los comienzos del siglo XXI, 3.620 millones de personas vivirán en ciudades y las que actualmente viven están en un 25% sumidas en la máxima pobreza.Para entonces trece ciudades de las quince mas grandes estarán en los países en desarrollo.

El año 1987 fué instituido Año Internacional de la Vivienda para las personas sin Hogar. He aquí que después de tres años, constituye para la IUFRO un promisorio futuro para que los Forestales se preocupen en la "Planificación del Espacio Urbano".

"LA LLUVIA DE LOS TIPALES"(Raining under Tipuana),constituye en esta contribución un "modelo descriptivo" para interpretar analiticamente la significancia de la vida forestal en la vida humana colectiva.

CONCEPCION TRANSFRONTERIZA
(Transboundary nature of Conception)

El árbol, es el protagonista en una ciudad de la Bio-diversidad(Conserving bio-diversity) por las siguientes razones: (UNEP 22-1988)

1. Son edificadores sociológicos y así superan la plataforma de significación ecológica y se ubican en la biogeocenológica

2. Son los promotores y sostenedores del número y frecuencia de las estructuras y sus secuencias (ordiness) para el montaje de las especies y sus patrimonios genéticos.

3. Son generadores en los habitats, comunidades y procesos.

Es también protagonista biometeorológico, por las siguientes razones: (Nicolis 1989)

1. Permiten la co-existencia de varios regímenes atmosféricos estables simultáneos bajo valores de parámetros meteorológicos determinados;

2. Neutralizan o modifican la severidad de la "dinamia caótica de los procesos atmosféricos", los cuales en principio son estados cerrados y se transforman en divergentes exponenciales con el transcurrir del tiempo horario. Esta sensitividad inicial para un observador meteorológico dado, es impredictible y así las predicciones sobre historias individuales pierden su significancia operativa. Esto es válido aún con la participación de pocas variables atmosféricas.

3. Ellos dan respuestas anticipadas o armónicas respecto a las que provienen de nuevas estrategias observacionales o modeladoras meteorológicas.

Las ciudades son un magnifico escenario para ejemplarizar la diferencia cientifica entre B i o g e o c e n o l o g í a y E c o l o g í a, hoy, ésta ya superada por aquella en la armonización cientifica de las realidades.

También la B i o m e t e o r o l o g í a desplaza a la M e t e o r o l o g í a y la C l i m a t o l o g í a, en entender la operatividad de riesgos y beneficios en el suceder de los estados atmosféricos.

Hoy, nuestra ERA, hay que humillarse a la N a t u r a l e z a para encontrar la "fuente de los caminos" que no nos brindan la Física y las Matemáticas.

Por ello, es meritorio que Japón haya adherido al concepto "M O T T A I N A I" (which suggests that to waste anything is to spurn the Creator and provider of all earthly resources)(UNEP 21 1988)

También debemos admirar el "N A V O D A Y A V Y D A A L A Y A en la India"fundamentando la educación avanzada para la niñez desprotegida. En el "greening education"(La Educación verde) que

propone esta contribución,la niñez es el asiento de los "escua-

drones verdes" en insertar los espacios verdes en la realidad vivencial de las modernas ciudades. Por ejemplo el rescate del plano aéreo de contaminación y abandono de las autopistas, transformándolas en "planos aéreos de amenidad y recreación". Los árboles representan los colonizadores en la r e s t a u r a c i ó n, tal cual lo son en las sucesiones naturales para la restauración de los "panoramas primitivos".

La niñez se inserta más sabiamente en el valor de estos panoramas y su reconstrucción. Ellos deben ser los fundadores de la VISION COSMICA EN LA EDUCACION AMBIENTAL y ser los cultores del ejercicio de la VISION ANGULAR en la apreciación de los horizontes urbanos.

Es menester que los estudiosos forestales aprendan a concebir la creación de los bosques sobre la base del ejercicio de los "factores de diseño" y así ser capaces de REDIMENSIONAR EL BOSQUE EN LA CIUDAD HABITABLE". El fruto divino es reformar el hombre viejo haciendo desaparecer los males de éste en aquella (la Ciudad habitable) y en la vida a su servicio.

LA LLUVIA DE LOS TIPALES
(Raining under Tipuana)

<u>Ecofisiología</u>

"Gutación" es una peculiaridad fisiológica. Con el advenimiento de la Ecofisiología se inició la justificación científica de esta peculiaridad adherida al "sitio"y con esta co-relación, la Ciencia debió aceptar en este contexto la participación de la Ecogenética.Los horizontes perceptivos de esa peculiaridad interesó con vehemencia la aplicación del comportamiento de las especies como "in-

-dicadores biogeocenológicos y bioclimáticos.

Las selvas vírgenes

Las he ponderado en el interior de las selvas vírgenes subtropicales en las estribaciones de la "Cuenca del Plata"(entre el Trópico de Capricornio y el paralelo 30º de latitud Sud,entre los meridianos 50º y 60º longitud oeste). Aquí las especies gutan en presencia de "aridez atmosférica" y no lo hacen en el interior de las selvas. Sí en los bordes exteriores de las "abras o milpas". McNary, citado por Braun Blanquet(1956), dió testimonio de ello, sin que ningún científico después de él, hasta mis días, lo haya nuevamente observado y evaluado.

Fenología Urbana

Sin duda que los registros fenológicos se adhieren a este escenario científico y así fue posible "especializar" sucesos que eran "frutos observacionales" de variabilidades estacionales físicas,biológicas y fisicoquimicas.Hoy, los ciclos bio-geo-quimicos condicionan la regularidad biológica de estos ritmos biológicos

Ecotones

La resiliencia,la resilencia, la redundancia biológica, la evolución y su antesala la "sucesión ecológica" fueron los autores del "marcos de situación" en que aquel escenario científico le toca actuar.Así, hoy, los ESCENARIOS ECOTONICOS son el rescate de toda esa capacidad biológica perdida, sin la cual es imposible reconstruir panoramas primitivos.

La Tipa

"La lluvia de los tipales", que aquí, les presento, es una bella observación de una especie forestal, TIPA (Tipuana tipu) en la "aridez biometeorológica" de una ciudad,Buenos Aires. La Tipa es la puerta de entrada, ya que sus dignos representantes adquieren portes selváticos de hermosa corpulencia peregrina, en el seno de la ciudad como acontece en sus genocentros naturales.La Tipa, en las llamadas "Yungas tucumano-boliviana"(en el extremo opuesto, occidental, a las cooordenadas geográficas de la Cuenca del Plata,sobre el meridiano 70º longitud oeste), es indicador fenológico y biogeocenológico de las mejores tierras agricolas en el seno de la selva alta amazónica.

Aquí esta un valioso eslabón que se ofrece a la Silvicultura urbana, en el mejoramiento de la bicdiversidad(conserving bio-diversity) de

La dimensión estética

las modernas ciudades.Hay que fundamentar la "dimensión estética" que es la nueva categorización de los Recursos Naturales en el Mundo, enriqueciéndola con la justificación aplicada de la Biometeorolcgía, como a continuación la señalo:

Sensitividad Sensibilidad Aridez

En toda ciudad, existen palmeras y coniferas. Son los "inmutables sensores" de la aridez biometeorológica.En el extremo opuesto están las especies parlantes por su sensitividad espacial y por su sensibilidad biológica a las variabilidades (lineares o ciclicas) de la aridez biometeorológica.Entre ambos extremos,hay una amplísima gama de especies de árboles y arbustosque en las modernas ciudades unen sus lenguages expresivos, con uno u otro extremo.

Laboratorios terrenos

Unas veces con lenguage diferencial con aquellas(palmeras y coniferas), otras veces con exclusividad de comportamiento. Hoy, las ciudades en que vivimos son "magnificos laboratorios terrenos" que nos costaría sacrificios si quisiéramos fabricarlos.Hay que aprovecharlos, en ellos podemos substanciar cientificamente la naturaleza intrínseca de las leyes evolutivas biológicas y fisicas. UNA CIUDAD ES UN DESIERTO EN MUCHOS PERFILES.

Simetría Virazones

Las ciudades modernas deben ser sin simetría y con abundancia de árboles. Es razón biometeorológica que en las ciudades simétricas, los intercambios atmosféricos recorren corredores que amortiguan las "virazones"(José Sanchez Labrador P.J."Las Misiones Jesuíticas" 1637 en la Cuenca del Plata).Así las atmósferas no se deslizan, no son extraidas por los movimientos naturales de la atmósfera fuera de la "pluma" especifica de cada lugar por la presencia de las irregularidades topográficas naturales y/o artificiales.

Nido y Techo

Los espacios verdes urbanos son más exigentes que los árboles en sí mismos.La falta de simetría, se convierten en "nido" de las variabilidades meteorológicas propias de las ciudades y la abundancia de árboles en "techo" para la neutralización inferior y superior de las variabilidades atmosféricas que son así transformadas en biometeorológicas.Los accidentes que ocurren en las ciudades son los efectos de estas transformaciones.

Si fuese posible estudiar las variables meteorológicas de los incendios forestales en el seno de una ciudad se podría "percibir" los parámetros biometeorológicos "conjugados" que ejercen los árboles, que no los pueden percibir las observaciones instrumentales meteorológicas sinópticas, de las cuales surgen riesgosos los incendios forestales libres en principio conmutables como inocuos. Los riesgos de los contaminantes en una ciudad dependen de la simetría interna de esa ciudad y los árboles mejoran esta situación, con solo mirarlos físicamente. Si se asocian ellos con espacios verdes, la capacidad física aumenta y el efecto de "techo" adquiere su doble significación BIO y METEOROLOGICA.

<u>Conjugados</u>

La primera, es obvia: la vida tiene riesgos con o sin techo y nuestras modernas ciudades crean experimentalmente la "dinámica caótica" de las variabilidades meteorológicas. Aquí radica la base del nuevo analisis científico de los espacios verdes. Se deben crear usando la Biometeorología y no las ciencias exactas y biológicas, exclusivamente. La "aridez biometeorológica" de una ciudad es un "promedio adverso" de componentes que poseen comportamientos erráticos en la atmósfera de una ciudad.

<u>Analisis disciplinario</u>

Aquí pretendo ejemplarizar el título de este apartado de mi contribución("La lluvia de los tipales"). Las tipas plantadas en una ciudad tan extensa y asimétrica como Buenos Aires y específicamente la Capital o Cono urbano, donde los tipales forman parte de espacios verdes amplios y arborizados como es el de un Jardín Botánico y Zoológico, la ausencia de aridez biometeorológica en la atmósfera del lugar, les hace producir la "lluvia" gutativa. La explicación fisiológica es conocida. Lo que no es conocido y mucho menos difundido en el público, es que la ciudad dentro de peculiaridades como "centro de calor", L A T E R M A L I D A D, es una pluma o estela subyacente, no ascendente, sino descendente. En las calles arborizadas por tipales, esta lluvia no se produce.

<u>Termalidad</u>

Es importante esta peculiaridad para una especie que arboriza una ciudad, por ser ella reguladora de la biometeorología del lugar y así dar dos caras de su eficiencia biológica en los espacios verdes urbanos. Por ausencia de

Eficiencia bienhechora

aridez en su atmósfera, multiplica la sensibilidad bienhechora de otros vegetales circundantes, sensibilidad que penetra los ambientes habitados que no poseen sistemas artificiales de climatizado.

La M i c r o m e t e o r o l o g í a, es un componente disciplinario de la biometeorología. Las modernas ciudades sufren por ese componente que no participa en la atmósfera de los "espacios verdes urbanos" por su condición dinámica, sino por su condición estática La "Silvicultura Urbana" ejemplariza las bondades del asocie forestal-arbustivo en accesos y espacios diversos. Es árdua tarea,como acontece en la "A G R O S I L V I C U L T U R A", una Nueva Cultura en la utilización integral de los suelos en el Mundo.Aquí el vocablo "integral" substituye al "autosostenido", En la Silvicultura Urbana acontece al revés y el publico en general no entiende ni por lo verbal, ni por lo imaginativo, el significado diferencial de estas "D I M E N S I O N E S" en las ciudades y en el territorio rural cincundante.

Agrosilvicultura urbana

Una ciudad ideal debería ser una "difusividad interpenetrada" de ambos territorios. Esto se puede observar en los asentamientos tropicales donde la selva virgen ha sido progresivamente depauperada pero no erradicada.

LA EDUCACION VERDE
(Greening Education)

Hace yá cuatro década la FAO preconizó que el bosque fuese linea curricular en la Enseñanza para las Escuelas de Nivel Primario. Si ésta "vida" se hubiese corporizado, hoy tendríamos ciudadanos pragmátizados y armónicos.

El ser interior

El color verde es sedificante y los ojos son las ventanas por las cuales el "ser interior" se comunica con el mundo exterior.Los ojos transforman el sublime tesoro de la "luz-color"y así la comprensión y el entendimiento cumplen su rol para una Humanidad sana.

Los espacios verdes en las modernas ciudades y en ellos y por ellos los árboles son "remansos mentales" que deben aprovecharse para que la Educación Pública Ambiental,tan jerarquizada y sufrida en esta Era, se transforme

en Educación Verde.

Principios

La Biogeocenología no se desvirtua como la Ecología, al admitir una corriente secundaria de pensamiento: "Los Ambientalistas". La Humanidad no ha recibido de la Ecología los principios operables para su Educación, sino el desorden que encarece "un cuidado" que no sabe practicar con eficiencia.

Decálogo Ecológico

Los umbrales de análisis que hasta ahora se han expuesto, son la "materia prima" para estructurar un nuevo contenido de la Educación ensamblada entre los diferentes niveles que institucionalmente existen en cualquier país. En el año 1982 concebí desde el plano de la Enseñanza Universitaria el "Decálogo Ecológico Interconectado" con los niveles de Enseñanza Primarios y Secundarios para la República Argentina. El Diagrama de Desarrollo Comunitario de este Decálogo, es la base del Proyecto de Enseñanza a Distancia para Ecología en Recursos Naturales en la República de Paraguay. Los espacios verdes urbanos, son la Pedagogía básica dentro de este Proyecto.

Único camino

Es mi convicción, que este nuevo contenido en la Educación es el único camino que dispone la Humanidad de nuestra Era para concretar - "la espiritualidad de un nuevo ser"(Mottainai) y"la espiritualidad de un nuevo tener"(Navodaya Vydaalaya)(UNESCO,OIE 1989)

Vivir con ideales

Todo es sostenible si se cuida la "ESTRUCTURA DE LA NUEVA FAMILIA MODERNA" contra quién todo lo de este mundo trata de destruir.Pedagógicamente, los hijos reciben la "matriz generadora" del eje de unión de los padres y ninguno de ellos independientemente le pueden dar esa "matriz". Los espacios verdes urbanos son la expresión de la capacidad de vivir con ideales.

Las"ciudades golpeadas" como las que se forman sin regulación panorámica y aquellas que nacerán por seres humanos que se agolpan llevando en sus mentalidades el "tugurio de la pobreza" necesitan conocer y vivir en los umbrales del analisis aquí realizado. La pérdida de los Recursos Naturales en el Mundo nos dejan la Enseñanza de cómo recrearlos donde por inercia viviran concentrados los seres humanos.

PLANIFICACION DEL PANORAMA URBANO
(Urban Landscape Planning)

La ecuación recíproca (Feedbacks) para las ciudades habitables;la recuperación de las que no lo son y el encarecimiento de las que potencialmente surgirán, es humilde en niveles sólida para el entendimiento y fervorosa para el ejercicio de la voluntad ciudadana:

LA EDUCACION VERDE

⇅

ESTRUCTURA MODERNA DE LAS CIUDADES ⇆ ESTRUCTURA DE LA FAMILIA MODERNA + HABITAT
(significación del Hiperespacio)

⇅

LA PLANIFICACION DEL PANORAMA URBANO

Declinación Mental — Crear bosques utilizando factores de diseño,permite crear ciudades cuyas calles sean parquizadas substituyendo la tradicional centralización de los espacios verdes en parques,plazas y jardines. Todo el espacio terreno y aéreo de una ciudad debe embeberse de la dimensión estética y la amenidad de los espacios verdes.No solo las calles serían mas anchas, sino también las veredas y aunque los edificios fuesen altos, elloa permitirían disfrutar de la presencia de horizontes que no produzcan la d e c l i n a c i ó n m e n t a l de las actuales ciudades.

Procesos — Si el ser humano se "desertiza", así,adquiere hábitos conductales que "desertifican".Con lo primero se hace victima de un proceso dinámico; con lo segundo, hace victimas con un estado de pobreza.

Cuarta Dimensión — HABITAT, es un H I P E R E S P A C I O, no un sitio.( ).Todo el contenido bio-geo-cenológico del Planeta. se hace un componente indispensable para

la ciudad habitable.

Disipación Saultriness

En las actuales ciudades los procesos de disipación energética son e x t r i n s e c o s para las creaturas inanimadas y son i n t r i n s e c o s para las vivientes y así viven - "encapsuladas" víctimas de un streess de inconciente sufrir que les inhibe hasta la capacidad de diálogo.La personalidad necesita de la plasticidad de imágenes dentro de la rigidez celdiforme de las ciudades sin espacios verdes urbanos.

La Biometereología en las actuales ciudades produce "saultriness" resultado (+) del Zeitgeber sobre los mecanismos sircadianos.

(+) parámetros biometeorológicos y geomédicos (Videla Pilasi 1980)

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PROBLEMS, PERSPECTIVES, APPROACHES:

HARVESTING ENERGY WOOD IN SCANDINAVIA AND CENTRAL EUROPE

Jørgen Baadsgaard-Jensen

Skovteknisk Institut
Danish Institute of Forest Technology
Frederiksberg, Denmark

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SUMMARY

The volume of wood harvested and exploited for energy production in Europe is often underestimated because only forest wood residues are considered in this connection. About 40% of the wood harvested in Europe is used for energy, but only in the Scandinavian countries wood residues from the forests are harvested for energy on a large scale. Wood fuels will be competitive with other fuels only if they are subsidized, and only the Scandinavian countries have seen to it that the use of this domestic energy resource is encouraged by subsidization. However, future research may improve the competitiveness of energy wood, especially research in integrated harvesting of industrial wood and energy wood. It seems likely that the environmental aspects of energy consumption in general, and the greenhouse effect in particular, will lead to subsidization of energy wood in many more European countries.

Keywords: Harvesting, energy wood

INTRODUCTION

Most of the European research in energy wood harvesting concentrates on the harvesting of wood residues for energy purpose. Much effort is devoted to the development of methods to harvest small trees, tops and branches for fuel, e.g. by chipping. Another main field of research and development is short rotation forestry. Both R & D fields are attractive, firstly because potentially great volumes of energy wood are available, and secondly because the novelty value of the R & D results obtained is likely to be high.

However, it may be argued that the application in practice of the R & D results is somewhat wanting when measured on the basis of the actual amount of wood used for energy production. In most European countries hardly any fuel chips are cut from forest wood residues, and the short rotation energy forest areas are modest.

It is therefore often assumed that the harvest of energy wood, and for that matter any application of wood for energy, are reserved for a narrow circle of enthusiasts and for the few countries who have chosen to encourage the application of wood for energy by taxation of fossil fuels and subsidization of renewable energy sources. However, this assumption is false. The harvest of energy wood and the application of wood for energy production are extremely important for the future growth of the European forests.

The fuelwood production decreased from the early 1950'es until the late 70'es, when it began to increase again. Today fuelwood accounts for about 15-20% of the total harvest in Europe. According to the official FAO/ECE statistics it is 15%, but FAO/ECE estimates the true proportion to be 20%. The decrease in the production of fuelwood was compensated for by a corresponding increase in the production of industrial wood. Hence more industrial waste wood became available for energy production. FAO/ECE 1986 estimated the application of wood for energy in Europe in 1980, including industrial wood waste, wood equivalent in pulping liquors, etc. to be about 165 million m3, i.e. more than 40% of the total volume harvested in 1986. Although the figures are almost 10 years old, recent statistics indicate no change. According to the FAO/ECE statistics the total harvest as well as the fuelwood harvest were rising during the 80'es, although the latter may have slowed down by the end of the decade.

The use of wood for energy in Europe is expected to increase in the years to come. More wood is harvested for industrial purposes, and more industrial waste wood wil become available for energy production. In contrast, the harvest of forest wood residues is not at present expected to increase.

PROBLEMS

The rising prices of fossil fuels in the late 70'es and early 80'es made it attractive to also use wood fuels. Considerable research and development initiatives were implemented on the subject of energy wood harvesting. But when by the end of the 80'es the prices of fossil fuels began to go down, many research and evelopment projects in harvesting and application of energy wood were discontinued. It is evident that the application of energy wood and thus also the harvest of energy wood are greatly dependent on the price of the competing energy sources.

Conventional firewood gained most from the rise in fossil fuel prices. Firewood will often be competitive with fossil fuels because it is used for domestic heating in private homes, and they pay more for their energy than any other consumer. In addition many people are able to cut firewood for home use cheaply in the forest, and by tradition many foresters produce firewood to heat the buildings of the forest property. Also the consumption of industrial waste wood for energy increased; in principle the industry who does not convert its waste wood into energy must pay the costs of removing it. Large-scale conversion of wood residues into fuel chips was seen only in countries where wood fuels had been made competitive with fossil fuels by subsidization and taxation, respectively, i.e. primarily in Sweden, Finland, Denmark and, to some extent, in Norway. In the other European countries the harvest and appli-

cation of energy wood as whole-tree chips or similar assortment was very limited.

In countries who did subsidize the application of energy wood, or where the direct and indirect subsidies were very small, only small-scale chip production was carried out. The small-scale chip production was economically feasible for the same reasons that had made the expanding firewood consumption possible. Fuel chips were used for domestic heating while the price of other energy sources were at their highest. The most costly equipment required for chip production, tractor and trailer, could be used for other purposes most of the year, so only some of the costs of this equipment could be charged to the production. Normally the labour costs incurred to tend the chip boiler are not included in the calculation of the price of heating a private home with chips.

Large-scale and professional energy wood harvesting systems were developed in countries with major subsidization of energy wood application. One condition for large-scale energy wood harvesting is the presence of major consumers. The presence of major consumers makes it possible to rationally organize the transport of wood from forest to consumer, and due to the high production, the cost per energy unit produced will be reasonably low.

The different levels of taxation and subsidization in the various countries imply that the major consumers profiting by the use of energy wood are different, too. Hence each country has developed its own harvesting systems. In the early 80'es the Swedish pulp industries had reason to fear inadequate supply of raw wood due to the competition from a subsidized energy wood consumption. This was the major reason for the Swedish pulp industry's accept of the tree-section system (Fagerlund 1984). By the tree-section system the felled, undelimbed trees are bucked into 4-6 m lengths and delivered to the industry, where the trees are delimbed and debarked. This system enables the pulp industry to determine how the energy part of the tree is to be exploited, and to safeguard the supply of stemwood for its own pulp production.

In Denmark it was impossible to sell the energy wood from the forests to the industries. This is due to the fact that Danish industries are exempt from energy taxes, whereas private consumers are charged with the highest taxes on fossil fuels in Europe.

District heating plants and co-generation plants became the major non-industrial consumers of energy wood. Finland, Sweden and Denmark have a long-standing tradition of heat distribution from district heating plants to private consumers. It will be difficult to introduce wood as a fuel for heat distribution from a district heating plant if no pipeline system is available.

NATIONAL DIFFERENCES

Energy wood is delivered as chips to district heating plants and co-generation plants. The chipping systems varies in the various countries, not because of the energy wood harvest itself, but because of other factors. In Sweden and Finland conifer logs are shortened into standard lengths. This allows a rational mechanized harvesting on clear cuttings where the wood resi-

dues are concentrated in strips. For this reason the majority of the fuel chips are harvested on clear cuttings. Drum chippers are better suited for operation on clear cuttings than disc chippers, and drum chippers are therefore widely used for energy wood harvest in countries where the chip production is mainly carried out on clear cuttings.

In Denmark most conifer timber is produced as whole stems, and the degree of mechanization on clear cuttings is therefore not so high, and only a limited amount of chips is produced on clear cuttings. The majority of the chips produced in Denmark is cut from small conifer trees from early thinnings. One reason for this is the small planting space used for stand establishment in Denmark. A rational harvesting method is combined row and selective thinning with simultaneous chipping. Disc chippers are best suited for the Danish chip harvesting systems in thinnings, and disc chippers are therefore widely used for the production of fuel chips in Denmark.

The Danish forests are marketing their fuel chips very actively. Chipping in the early thinnings has enabled the forests to carry out the first thinnings at the stage of growth when the effect of the thinning is optimal for the stand. At the same time the sale of fuel chips will fetch enough to pay the costs of thinning.

All countries are concerned with the impact on the nutrient balance of whole tree removal. Bark beetles are not a serious problem in Danish forests, so a system of summer drying has proven very effective. The trees intended for next winter's chip production are felled before 1st May and left on the site to dry over the summer. The system of 'sour' felling, where the trees are left with their crowns on to dry rapidly by respiration, is not feasible due to the denseness of the stands. The supply of light is so small that the respiration will stop as soon as the tree is felled. Instead the desired effect is obtained by leaving the trees in the forest to dry slowly during the summer months. The moisture content rises somewhat during the winter, but not so much that chipping cannot be done any time of the year. During the drying process the trees will shed their foliage, and thus the majority of the nutrients they contain is left on the site. Thanks to this system, chipping is allowed everywhere in Denmark without any restrictions. The system is not feasible in Sweden and Finland where bark beetles represent a serious problem in thinnings.

In general, the storage facilities are better in Sweden and Finland than in Denmark. In Denmark most district heating plants are situated in the centre of fairly small towns, and they are incapable of storing more than 2-3 days' supply at the time. The majority of the chips are therefore piled and stored in the forest, and the piles must be covered with tarpaulins to prevent excessive moisture content increase.

PERSPECTIVES

Admittedly, it was the taxation of fossil fuels and the subsidization of renewable domestic fuels that made the large-scale Scandinavian energy wood harvest possible. But the application of the harvesting systems in practice has led to further development of the systems. Information on the experience

gained in practice was collected, and the further development of the systems was based on the knowledge thus obtained of the requirements. Today (1990) less subsidization is required to make the large-scale exploitation of energy wood economically profitable. Due to the successful rationalization, the total harvesting costs in Denmark have been reduced by some 5-6% each year during the 80'es.

However, with the present price level of coal, oil and natural gas, energy chips and other forest fuels are unlikely to be able to compete with fossil fuels in Europe without some kind of subsidization.

There are three chances of increasing the competitiveness of energy wood. Of course oil, gas and coal prices may rise above their present level. It may be possible to develop more rational harvesting systems for industrial wood, by which the energy fraction, i.e. branches, tops and bark, are concentrated in such a way that they represent an easily accessible byproduct from the production of industrial wood. In that case most of the costs of harvesting this energy resource can be paid by the sale of the industrial wood. The third chance lies in the possibility of imposing environment taxes on the fossil fuels.

Environment taxes are already being discussed in Northern Europe. The main argument in their favour is the necessity of reducing the CO_2 emission and hence the greenhouse effect. However, if they are to produce the desired effect, the enviroment taxes must be high enough to make energy wood and other renewable fuels economically competitive. After some years of stagnating or even falling sale of fuel chips, the prospects are becoming brighter because of the chance of environment taxes on fossil fuels.

APPROACHES

As will appear from the above, the far greatest problem of energy wood harvesting in most European countries is the competitiveness of the fuel. A number of technically successful harvesting systems are in operation today, adapted to the varying terrain, site and stand conditions. A further reduction of the harvesting costs should remain the principal objective of the research and development carried out in this field.

An obvious subject for future R & D is the harvest and preparation of conventional firewood. Unfortunately, firewood has a low status in the eyes of the authorities empowered to provide funding for research, and in the eyes of the researchers. Although it is the greatest energy assortment produced by the forests of any country, very little R & D has been carried out in the harvest and preparation of firewood. The present technology for firewood processing has a low productivity compared to any other mechanized processing in the forest.

The chunk concept presents an obvious opportunity of rationalizing firewood processing. The concept was introduced by the North Central Forest Experiment Station, U.S. Forest Service (Arole et al. 1988). Experimental chunking machines are in operation in the U.S., Sweden and Denmark. All the

chunkers are suited for rational firewood processing, and the chunking system will multiply the productivity of firewood processing as compared to any other system known today. One drawback of the system is however the less regular shape of the firewood produced by chunking.

Like chippers, chunkers are capable of processing bunches of trees at a time, which makes it profitable to produce firewood from small trees. Hence some of the wood that goes to waste today may be sold as firewood.

Integrated harvesting of industrial wood and energy wood is another obvious R & D subject that may lead to a reduction of the costs of harvesting the energy wood. In principle all logging and transport is a kind of integrated harvesting. All industrial wood contains an energy fraction, the industrial waste wood.

In the course of the present decade most European forests will have to rationalize the harvest of small-dimensioned industrial wood, in order to enable the industries processing the small trees to compete on the world market. In Scandinavia the interest for R & D in multi-tree handling harvesting systems is mounting. It is realized that single-tree handling harvesting systems such as the modern single-grip harvesters cannot be rationalized much further. Multi-tree harvesting systems represent an obvious chance of applying integrated harvesting.

By the integrated harvesting methods the production of industrial wood from small thinning trees can be rationalized. But at the same time several of the systems will concentrate the wood residues at landings for more or less centralized processing (Brunberg 1989, Dahlin 1989, Suadicani 1989). Renewed research is required to clarify which of the multi-tree handling harvesting systems are best suited for the salvage of the wood residues for energy purpose, and where in the given circumstances it will be best to separate the energy fraction from the industrial fraction. This research was initiated on an international level by the International Energy Agency, IEA/BA TASK VI Activity 2 'Integrated Harvesting'.

A third field where rationalization may pay off is reduction of the storage costs for energy wood. Storage of fuel chips represents a fairly large proportion of the total costs of using this fuel. The fuel consumption of the heating plants is unevenly distributed over the year, and the forest owner wishes to be able to utilize the chippers continuously. This has necessisated large stores of fuel chips. Much research was carried out in order to clarify the parameters determining the costs of storing chips, e.g. moisture content development, biological activity, etc., in order to minimize the energy loss. Data collected in Denmark demonstrate that the costs of storing fuel chips amount to 20 to 30% of the total costs of production and handling until the moment of combustion.

A change of harvesting system may contribute to reduce the storage costs. Tree sections or whole trees may be stored instead of chips, or the production may switch from chips to chunks. Both methods will reduce the dry matter loss of the stored material (Nurmi et al. 1988).

A Danish research project starting in 1990 will investigate the possibilities of reducing the volumes of energy wood that we have to store today.

The project is intended to throw light upon key operations in the production chain from forest to district heating plant. The harvesting operation will be investigated with a view to identifying equipment for production of components other than energy wood, in order to enable the forest owners to adapt the harvest of energy wood to the requirements of the consumers over the year.

CONCLUSION

Energy wood will continue to be essential for Scandinavian and Central European forestry. The increasing concern for the environment is bound to make energy wood an important factor in the attempts to preserve the environment. Of course the use of wood for energy production is not enough to solve the problem of the greenhouse effect, but it may contribute to solving it. The application of energy wood and thus also the harvest of energy wood should in future be more integrated with the harvest and application of industrial wood. This integration will give the energy wood a chance of competing with other energy sources, and it will provide more concise information on the importance of wood fuels as a factor in the European energy supply.

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INCREMENTAL EFFECTS OF OIL AND PAPER SLUDGE ON THE HEAT CAPACITY OF *ROBINIA PSEUDO-ACACIA* L. FUELWOOD

Kae-Hwan Kim

Associate Professer
Department of Forestry

Jeonbug National University, Jeonju
Jeonbug 560-756, Seoul, Korea

FDC: 812.14: 176.1 *Robinia pseudoacacia* L.: 831.1

SUMMARY

The heat capacity in different mixtures of *Robinia pseudo-acacia* energy efficiency with either used lubricating oil, bunker crude oil, lamp oil or paper sludge was examined for incremental effects. The largest incremental effect of energy efficiency(38.6%) was achieved by mixing 0.05g bunker crude oil with 0.95g *R. pseudoacacia*. Mixtures of 0.3g lamp oil and 0.7g *R. pseudoacacia*; 0.1g used lubricating oil and 0.9g *R. pseudoacacia* provided of incremental effects of 15.5% and 3.2%, respectively. However, paper sludge mixed with *R. pseudoacacia* did not resulted in any increase in heat capacity.

Keywords: Bioenergy, heat capacity, *Robinia pseudoacacia*

INTRODUCTION

Wood can be burned directly, or converted to charcoal, gases and liquid fuels. The need to convert wood to any of these forms is very much determined by the needs of the country or organization and also on the related economics. All the necessary technologies are in place but in many cases they are not fully developed or optimized (Zsuffa, 1986). In Republic of Korea, approximately 160 million trees of black locust (*Robinia pseudoacacia* L.) have been planted on 436,000ha since 1960s, for erosion control and fuelwood. Black locust because naturalized, and at the present time, it hinders the growth of other forest species of South Korea.

Black locust makes excellent fuelwood, and it is also one of the most promising species for biomass production in fuelwood plantations (Tarasenko and Svistula, 1980; Rowell and Carpenter, 1982; Stringer and Carpenter, 1982, 1986; Lainging *et al.*, 1985; Furuset and Gisleurud, 1986; Lahiri, 1986; Pages 1986). There is a shortage of wood in Republic of Korea, and there is interest in using oils and paper sludge in mixture with fuelwood to in-

crease its heating capacity.

EXPERIMENTAL METHODS

Black locust wood samples were collected from the stem of tenyear old trees, air dried, chipped into small pieces, and reduced to powder with a pulverizer. The mixing materials were collected from factories in South Korea and consisted of used lubricating oil, bunker crude oil or paper sludge. The wood to oil or sludge ratil was increased by at 5% intervals. The heat capacity was determined as calories per gram and measured with K.S. 3702-82 for pure wood and materials used for mixing, as well as for each of the mixture tested.

RESULTS AND DISCUSSION

Some of the mitures with oil showed an incremental effect on heat capacity of black locust wood. However, the mixtures of wood paper sludge did not show such an effect. The results of mixing lubricating oil with black locust wood are shown in Table 1. Some of the light mixtures (30% or less by weight) of lubricating oil resulted in slight incremental effect on heating capacity (+1.6 to +3.2%). Table 2 shows that mixtures of bunker crude oil in 5% to 20% proporsion resulted in a +3.4% to +38.6% increase in heat capacity of black locust firewood. Table 3 shows that mixtures of 20% to 45% of lamp oil resulted in increased heat capacity (+1.1% to +15.5%), mixtures of paper sludge with black locust wood did not result in increased heat capacity.

It is interesting to note that different mixtures of oils gave incremental effects, and also that these effects were various, and unrelated to the calorific value (calories/gr.) of oils used. For example, used lubricating oil (10,830 cal/gr.) resulted in +1.6% to +2% increase in calories. Value when added to wood in 5% to 30% mixtures, lamp oil (11,020cal/gr.) resulted in +1.1% to 15.5% increases when added to wood in 20% to 45% proportions (maximum increase of +15.5% of 30% proportion), and bunker crude oil (10,380 cal/gr.) resulted in +3.4% to 38.6% increase in heat capacity of wood when added of 5% to 20% proportion (maximum increase of heat value of 38.6% of 5% addition to wood).

One can only speculate on this phenomenon of increased heat capacity of the studied mixtures. In this studies it occurred only with oils, having higher calorific values than wood, and it did not occur in mixture with paper sludge, which had a lower calorific values than the black locust wood. It is likely that mixtures of oil contributed to more complete and effective buring, resulting in increased calorific values of the mixed fuels. In these experiments, we used pulverized wood, which may

Table 1. Tested data of heat capacity between used lubricating oil and R. pseudoacacia (cal/g)

No.	Used lubri.oil W.	Heat cap.	R. pseudoaca. W.	Heat cap.	E.H.cap. of 1g(1)	R.H.cap. of 1g(2)	I.E(%)*
	1.00g	10,830	1.00g	4,740			
1	0.95	10,288	0.05	237	10,525	10,491	-0.3 g
2	0.90	9,747	0.10	474	10,221	10,150	-0.7 h
3	0.85	9,205	0.15	711	9,916	9,720	-1.9 i
4	0.80	8,664	0.20	948	9,612	9,280	-3.5 j
5	0.75	8,122	0.25	1,185	9,307	8,830	-5.1 mn
6	0.70	7,581	0.30	1,422	9,003	8,580	-4.7 l
7	0.65	7,039	0.35	1,659	8,698	8,270	-4.9 lm
8	0.60	6,498	0.40	1,896	8,394	8,050	-4.1 k
9	0.55	5,956	0.45	2,133	8,089	7,800	-3.6 j
10	0.50	5,415	0.50	2,370	7,785	7,380	-5.2 n
11	0.45	4,873	0.55	2,607	7,480	6,660	-10.9 p
12	0.40	4,332	0.60	2,844	7,176	5,920	-17.5 a
13	0.35	3,790	0.65	3,081	6,871	6,110	-10.3 o
14	0.30	3,249	0.70	3,318	6,567	6,670	+1.6 f
15	0.25	2,707	0.75	3,555	6,262	6,412	+2.4 d
16	0.20	2,166	0.80	3,792	5,598	6,130	+2.9 c
17	0.15	1,624	0.85	4,029	5,653	5,823	+3.0 a
18	0.10	1,083	0.90	4,266	5,349	5,520	+3.2 b
19	0.05	541	0.95	4,503	5,044	5,146	+2.0 e

W= Weight; E.H.cap.= Expect heat capacity; R.H.cap.= Real heat capacity; I.E= Incremental effect
* Values with the same letter are not significantly different

Table 2. Tested data of heat capacity between bunker crude oil and R. pseudoacacia (cal/g)

No.	Bunker-C oil W.	Heat cap.	R. pseudoaca. W.	Heat cap.	E.H.cap. of 1g(1)	R.H.cap. of 1g(2)	I.E.(%)*
	1.00g	11,380	1.00	4,740 cal			
1	0.95	9,861	0.05	237	10,098	10,060	-0.4 e
2	0.90	9,342	0.10	474	9,816	9,660	-1.6 f
3	0.85	8,823	0.15	711	9,534	9,390	-1.5 f
4	0.80	8,304	0.20	948	9,252	9,110	-1.5 f
5	0.75	7,785	0.25	1,185	8,970	8,780	-2.1 fg
6	0.70	7,266	0.30	1,422	8,688	8,410	-3.1 ij
7	0.65	6,747	0.35	1,659	8,406	7,903	-5.6 k
8	0.60	6,228	0.40	1,896	8,124	7,910	-2.6 gh
9	0.55	5,709	0.45	2,133	7,842	7,610	-3.0 ih
10	0.50	5,190	0.50	2,370	7,560	7,280	-3.7 j
11	0.45	4,671	0.55	2,607	6,738	4,610	-31.5 l
12	0.40	4,152	0.60	2,844	6,996	4,930	-29.5 m
13	0.35	3,633	0.65	3,081	6,714	5,310	-20.9 o
14	0.30	3,114	0.70	3,318	6,432	5,450	-15.3 n

No.	Bunker-C oil W.	Heat cap.	R. pseudoaca. W.	Heat cap.	E.H.cap. of 1g(1)	R.H.cap. of 1g(2)	I.E.(%)*
15	0.25	2,755	0.75	3,555	6,150	5,820	-5.4 k
16	0.20	2,076	0.80	3,792	5,868	6,070	+3.4 d
17	0.15	1,557	0.85	4,029	5,586	6,170	+10.4 c
18	0.10	1,038	0.90	4,266	5,304	6,708	+27.8 b
19	0.05	519	0.95	4,503	5,022	6,960	+38.6 a

W. = Weight; E.H.cap. = Expect heat capacity; R.H.cap. = Real heat capacity; I.E. = Incremental effect
* Values with the same letter are not significantly different

Table 3. Tested data of heat capacity between lamp oil and *R. pseudoacacia* (cal/g)

No.	Lamp oil W.	Heat cap.	*R. pseudoaca.* W.	Heat cap.	E.H.cap. of 1g(1)	R.H.cap. of 1g(2)	I.E.(%)*
	1.00g	11,020	1.00g	4,740			
1	0.95	10,469	0.05	237	10,756	10,660	-0.4 efg
2	0.90	9,918	0.10	474	10,392	10,398	-0.8 ef
3	0.85	9,367	0.15	711	10,078	10,060	-0.2 ef
4	0.80	8,818	0.20	948	9,764	9,720	-0.5 hfg
5	0.75	8,265	0.25	1,185	9,450	9,260	-2.0 hg
6	0.70	7,714	0.30	1,422	9,136	9,076	-0.6 efg
7	0.65	7,163	0.35	1,659	8,822	8,510	-2.9 h
8	0.60	6,612	0.40	1,896	8,508	8,410	-1.2 hfg
9	0.55	6,011	0.45	2,133	8,194	8,136	-0.7 efg
10	0.50	5,510	0.50	2,370	7,880	7,890	+0.1 d
11	0.45	4,959	0.55	2,607	7,566	7,648	+1.1 d
12	0.40	4,408	0.60	2,844	7,252	7,418	+2.3 c
13	0.35	3,857	0.65	3,081	6,938	7,346	+5.8 b
14	0.30	3,306	0.70	3,318	6,624	7,650	+15.5 a
15	0.25	2,755	0.75	3,555	6,310	6,710	+2.0 b
16	0.20	2,204	0.80	3,792	5,996	6,130	+2.2 c
17	0.15	1,653	0.85	4,029	5,682	5,621	-1.1 efg
18	0.10	1,102	0.90	4,266	5,368	5,250	-2.1 h
19	0.05	551	0.95	4,503	5,054	4,752	-16.4 i

W. = Weight; E.H.cap. = Expect heat capacity; R.H.cap. = Real heat capacity; I.E. = Incremental effect
* Values with the same letter are not significantly different

have also contributed to complete soaking of oil and effective burning.

As a conclusion this study demonstrated some possibility of incremental effect of energy efficiency for different mixtures oil and black locust, however, further studies are needed to determine the theoretical background for incremental effect of energy efficiency with some materials.

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PROBLEMS AND PERSPECTIVES OF FOREST BIOMASS ENERGY IN INDUSTRIALISED COUNTRIES

C P MITCHELL

Wood Supply Research Group
Forestry Department
Aberdeen University
Aberdeen, AB9 2UD, UK

SUMMARY

Two types of problem face the development of short rotation forestry in the industrialised countries - philosophical and technological. Philosophical problems relate to problems of definition, land use, and macro-economics and sociological and environmental issues and are essentially beyond the control of the producer. Technological problems deal with practical difficulties. The main technological problems concern increasing mechanisation (to reduce costs), establishing plantations rapidly with high-yielding clonal material which is resistant to the most serious pests and diseases (to increase yield). However, the current changes in the way society perceives and values its environment and utilization of natural resources may have a bigger impact on the development of biomass production systems than any changes in technology.

INTRODUCTION

The problems facing the development of short rotation forestry in the industrialised countries divide essentially into two main groups - philosophical and technological. The philosophical problems relate to problems of definition, land use, and macro and micro-economics whereas the technological problems are more mundane dealing with such difficulties as harvesting or controlling diseases.

PHILOSOPHICAL PROBLEMS

The concept of short rotation intensive culture was developed in the mid 1960s for the production of fibre for the pulp and paper industry. However, as a consequence of the oil crises in the early 1970s the production systems under development were redirected towards producing wood for energy. At this time short rotation forestry was considered as a land use for otherwise marginal farmland and natural or cut-over peatland. Consequently much of the early effort was directed at selection of suitable species and cultivation systems for essentially very poor sites.

Since that time land-use policy has been put into turmoil due to over-production from agricultural land leading to much agricultural land now being surplus to requirement. The actual policy for dealing with this problem varies from country to country but essentially the mechanism is similar. Land is taken out of production or another agricultural (non-food) enterprise is put in place. One of the "new" uses of such land is the establishment of forestry, either as a soil conservation measure or for some other environmental consideration as well of course as producing wood. This wood can supply a variety of end uses ranging from timber for construction through to wood for fuel. The important point arising is that better quality land is likely to be available for short rotation biomass plantations than was previously the case.

The current suggested solutions to the agricultural surpluses problem has generated a problem which predominately concerns the nature of the forestry crop which is established ie one of definition or understanding of short rotation forestry which in turn revolves around the projected end use for the produce.

Short rotation forestry means different things to different people and cannot be defined simply. Rather, it has to be defined in terms of production strategies which embrace the production, harvesting, storage and delivery systems necessary to supply a given end user. Production in turn needs to be defined in terms of species, spacing, rotation (or cutting cycle), silvicultural system (coppice or single stem), and intensity of management. Defining the system in such a fashion allows systems analysis and financial appraisal to be more readily practised. It is only by examining the production system in such a fashion that the potential of the technology, problems and limitations of the practice can be highlighted.

The discussion of potential production systems and supply strategies is almost open ended and herein lies one of the fundamental problems facing the technology in industrialised countries. The problem lies not necessarily with the production technology per se but with the dilemma of whether to produce feedstock for energy or for the forest products industry. The

crux lies in the relative economics of the production systems. Wood for pulp and board production has a higher value than wood for energy in the present markets. Also, with longer rotations unit costs of production are cheaper (due mainly to reduced harvesting costs with larger trees). In Europe this issue is further compounded by the need to increase the home grown production of feedstock for the pulp and board industries to offset massive trade imbalances. The result is that in Europe short rotation forestry is currently considered mainly as a means of producing raw material for the forest products industry, energy is the residual material left after the industry is supplied. One of the arguments raised in this regard is that producing paper or board is producing a higher value added product which therefore makes better use of the land. This argument only holds in practice when material for paper and board manufacture is in short supply and energy is in surplus or is cheap, such as is the case in many of the industrialised countries at the moment. It is only when energy is in short supply or is expensive as in the early 1970s that short rotation forestry for energy appears attractive.

The situation can be changed significantly if a government makes a policy decision to make use of renewable energy sources or domestic fuels. This forces a country back on to its own natural resources, such is the position in Sweden where a decision has been taken to shut down the nuclear power generating capacity in the near future. With all the hydropower capacity taken up, apart from importing coal or natural gas Sweden is forced to consider biofuels either from municipal waste, from the conventional forestry sector or through growing short rotation energy plantations. The other main factor in their energy policy is that of increased energy efficiency.

This latter factor links in with the other concern which is starting to dominate the debate about energy policy. This is the environmental issues of greenhouse gases and global warming, and "acid rain". Increasing energy efficiency can lead to massive reductions in pollutants including the emissions of greenhouse gases. Another element in the greenhouse gas issue which has a direct impact on short rotation energy forestry is that trees when they grow sequester carbon and hence act as a sink for CO_2, one of the main greenhouse gases. Even when burnt the biomass is not contributing to the net build up of CO_2.

One of the consequences of "acid rain" and past agricultural practices is that there is a massive build up of nitrates in the soil, particularly in southern Sweden. Such is the magnitude of the problem that fertilisation of forests is not now permitted. Short rotation forestry crops are very demanding of nutrients and could be used to "filter" the nitrates thus reducing pollution of the ground water. The potential uses of short rotation forestry crops as biological filters are wide ranging from filtering industrial effluents through to disposal of municipal sewage sludge or run-off from roads.

Whilst short rotation forest crops may be of introduced species, with all the problems that that entails, others will be of native species and if grown on previously arable land may well lead to habitat diversification.

Short rotation forest energy plantations cannot be looked at in isolation, they are just one of many production systems making use of the land. Further they are being operated within the wider context of the environment and society with which they interact. Perhaps the current changes in the way society perceives and values its environment and utilization of natural resources will have a bigger impact on the development of biomass production systems than any change in technology. Hence, in order to understand the development of the technology, whether at the philosophical or technological level, and be able to control it the wider view has to be taken and this can best be achieved by adopting a systems approach to analysis.

TECHNOLOGICAL PROBLEMS

The technological problems facing potential practioners of short rotation forestry for energy are those that relate to the practical implementation of the technology ie those relating to which species/clones to use, levels of productivity, management and cultivation system, weed, disease and pest control, harvesting, preparation, storage, drying and transport.

The key to successful application of the technology is to produce and deliver the product desired by the end user as cost effectively as possible and to at least breakeven on the operation. Under present market and production conditions this is not possible without some form of subsidy or price support. Market conditions and hence prices demanded for the raw material can change due to many circumstances as outlined above but these are not in the control of the producer. Hence, the producer has to direct his attention to producing the material cheaper either through increasing productivity, reducing costs or preferrably both.

Short rotation forestry is a new crop which is currently moving from R&D into practice. Willows and poplars in the main are planted usually as unrooted cuttings, at high planting densities, up to 40,000/ha but more normally in the range 5 - 20,000/ha. Complete weed control using herbicides in the first two years is absolutely essential. The crop is grown as coppice with harvesting every few years and crop regeneration from the cut over stool. Harvesting cycles vary with species, site and size of end product required by the end user and tends to be in the range 3 to 5 years and even up to 10 years in some cases. Coppice stools are likely to be replaced every 20 to 30 years,

depending upon longevity, which is influenced by the frequency of cutting, and incidence of disease.

Probably the most important facet of the short rotation biomass crop is that it will be grown on farm land by farmers and the level of management and intensity of cultivation, tending etc will be more akin to an agricultural than forestry crop.

These are very intensive management regimes which, with the density of the crop and the production economics, implies a high level of mechanisation. However, it is a relatively simple production system providing sufficient is known about it to enable potential problems to be handled. Unfortunately, whilst it is thought that we have sufficient knowledge to move from an R&D stage to practice, this is not necessarily the case. In fact it is in this development stage that the "real" problems start to surface. Typical of these is that of pests and diseases - these start to occur once the host population reaches a certain size and the pest or disease population is of a size to cause problems. There are two examples of this phenomenon which have occurred in the last few years and both refer to Salix crops. A major problem that has arisen is the widespread incidence within Northern Europe of a rust disease (Melampsora epitea). The incidence of this disease built up over several seasons until it was causing a major problem of defoliation and consequent loss of production, leading to the demise of certain clones which were too susceptible to the disease. Unfortunately, some of these clones were among the higher yielding. However, the incidence of the disease in 1989 seems to have declined, whether because of a loss of vigour in the pathogen or the microclimate prevalent at the time (1989 was a much drier and warmer summer in northern Europe than the previous three summers) is unknown.

A pest problem that occurred recently was the incidence of a midge (related to Rhabdophaga terminalis) which removes the terminal bud in the latter part of the growing season and has been blamed for a 50% reduction in biomass production on some willow species in Sweden.

To some extent problems of pests and diseases are related to the performance of a particular clone on a given site. Again, whilst a large number of trials have been established on an equally large number of sites the information coming from them is not necessarily feeding through to the practice; it is to the extent that fairly broad matching of clone to site is possible through the use of professional judgement but unfortunately this is rarely based on systematic trials and analysis of data. A significant factor of this problem is that the development of the technology is moving faster than the scientific data which is really needed to drive it successfully. As an example, clone site trials established a few years ago are now yielding valuable information on the relationship between site, clone, cutting cycle, stool longevity and productivity; such trials need to be run for at least 10 years to give reliable information.

However, many of the clones used in such trials have succumbed to disease (valuable information in itself) or have been superseded by superior clones in terms of field performance in the early years. Unfortunately, this will always be a problem in the short to medium term.

It is possible to live with this problem and put the information to some use, eg through the development of an expert system or more likely a decision support system. Where there is sufficient information within large programmes this can be held in a database and interrogated through the decision support system. If programmed correctly the information in the databases can be sifted and the optimal matching of clone to site can be accomplished. Such a support system should also provide information on the operations necessary (eg planting density, herbicide types and dose rates, cutting cycles etc) to maximize yield or financial return (not necessarily the same procedures).

To date development of mechanization of operations has been limited to the areas of planting and harvesting. Where there has been development it has been where there has been a need. A planter was modified to allow expansion of a planting programme limited by availability of labour and the planting window. Harvesting machines are being developed as there is a need to cut an increasing number of experimental plantations.

There has as yet been no or little commercial involvement. Clearly machine manufacturers will not move in to develop new machines until they see a sustained commercial exploitation of short rotation coppice and plantings of such a scale that they will see a return on their development costs. Interestingly, we are now seeing small engineering companies in Sweden starting to build equipment or tractor attachments specifically for operations in short rotation biomass plantations.

In some regards mechanisation of operations is not a problem in as much that if there is a need an engineering solution will be found. However, the technological solution may not be acceptable to the industry as the cost is too great. The main technological problems that are being faced currently involve the singularisation of cuttings (essential for the development of automatic cuttings planters) and the handling of cut coppice sprouts following harvest.

For many establishment operations existing agricultural equipment can be used with only slight modification. However, when it comes to tending operations after the first year there are considerable problems to be encountered with access to the crop. After a couple of years height growth can be several metres and unless there is a very dense road network it will be impossible to mechanise spraying of the crop. The density of the crop will virtually prohibit mechanical tending operations at ground level. Agricultural equipment will not be adequate and aerial application may not be viable due to small plot size and

environmental restrictions. Hence biological and management solutions need to be found ie development of disease resistant clones and adjustment to planting density.

As the costs of harvesting, chipping and delivery can amount to in excess of 50% of the total delivered cost much development work has been targetted on increasing efficiency and reducing costs. However, to date no satisfactory solutions have been forthcoming.

One problem lies with the fact that coppice crops will be grown on a variety of cutting cycles and spacings. The combination of cutting cycle and spacing will determine the dimensions of the crop to harvest and the yield. Both factors will influence the choice of harvesting system. Where the cutting cycle is short, say 3 years, and the spacing narrow, say 1 x 1 m, then relatively small tractor mounted machines which sever the crop with a circular saw are appropriate. Where longer cutting cycles are practiced at wider spacings then heavier duty machines, perhaps mounted on a forestry tractor or forwarder chassis, are required. Crop severance may still be by circular saw. If crops are on a ten year cutting cycle then feller buncher technology is more appropriate.

Two prototype coppice harvesters are currently being used, the ESM machine in Sweden and the Loughry machine in the UK. Both are semi-trailed behind agricultural tractors, cut the crop with circular saws and produce bundles, 2.5t for the ESM and 300kg for the Loughry. Productivity is broadly similar for both machines at around 1.0 ha/day. This needs to be increased if the operation is to be economic.

The problem that all coppice harvesters face, and which has not been satisfactorily solved, is that of handling the material once it has been cut. This applies to production of bundles as well as to comminuted material. The nature of the cut coppice sprout makes it difficult to handle. It is not straight, has side branches and is not amenable to compression leading to problems of bundles falling apart after tying. For comminuted products the problem lies with the difficulty of orienting the material to the chipper head at the right angle to give an homogenous product.

Storage and drying are aspects that need to be considered in the supply chain. The point at which the operations occur, the nature of the stored product and the desired degree of drying are all determined by the overall supply strategy. The current favoured approach is for the bundles to be stored at the side of the field to allow some passive drying to occur, up to 20 percentage points reduction in moisture content has been demonstrated.

Transport is not really a technological problem as existing technology is available. Conventional pulp wagons can be used

for transport of bundles and chip vans can be used for a comminuted product. However, the low bulk density of these products, particularly bundles, makes transport an expensive operation.

CONCLUSIONS

There is a considerable potential for production of biomass for energy; the size of that potential depends on interpretation (or manipulation through government policy, subsidies and price support) of future markets for energy, food and forest products.

On a policy level support for energy forestry may come through governmental solutions to the agricultural surpluses problem and increasingly through a recognition of the benefits that short rotation forestry has to problem of global warming and the accumulation of greenhouse gases. Further potential benefits of short rotation forestry are seen with the use of the crop as a form of biological filters to clean up industrial effluents and aid in the disposal of municipal sludge. Therefore, whilst short rotation forestry for energy might not appear on the surface to be an economically viable proposition as compared to producing wood for pulp its economic position could well change if the environmental benefits are factored into the equation.

In order to establish energy forestry as a viable alternative agricultural crop solutions to some key questions need to be established. These questions relate to increasing the yield (productivity) and decreasing the costs of production.

These two key issues are best achieved in the short term by developing cost effective production systems and improving the costs of harvesting and delivery. In the longer term the solution to the problem of increasing yield (and resistance to pests, diseases, and herbicide sensitivity) can only be met through a sustained and systematic breeding programme.

In contrast to the problems facing the development of energy forestry systems in developing countries which are predominantly ones of soil conservation and sociology those in the industrialised countries relate to increasing yield and decreasing cost. As a consequence of this position the main problems facing the technology concern increasing mechanisation (to reduce costs), establishing plantations rapidly with high-yielding clonal material which is resistant to the most serious pests and diseases (to increase yield).

However, in the final analysis it is not the technological problems that are holding back the development of short rotation biomass for energy plantations but ones of macro-economics and

attitude. Perhaps the current changes in the way society perceives and values its environment and utilization of natural resources will have a bigger impact on the development of biomass production systems than any changes in technology.

In order to develop the technology of biomass production into practice a clear understanding of the whole system is required. This can only be achieved through a systematic examination of all the issues, this is best done through adopting a systems approach, linking into a decision support system.

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PROBLEMS AND PERSPECTIVES OF FOREST BIOMASS IN DEVELOPING COUNTRIES.

Lisbeth Sennerby-Forsse

Director of Research
Department of Ecology and Environmental Research
Swedish University of Agricultural Research
Uppsala, Sweden

SUMMARY

A literature review of the recent wood fuel use and demand in developing countries points towards an increase of the woodfuel crisis in the near future. Planting of trees remains the most important activity to increase the wood supply and restore a disturbed environment. Reforestation can however, be done in many different ways. The production systems most frequently encountered for improving life conditions and restore the environment in and around rural societies are: soil conservation systems, multipurpose tree production, agroforestry and industrial plantations. By means of a cross disciplinary approach, reforestation should be part of an integrated system to diversify land use.

INTRODUCTION

Nobody can tell how much wood is used for energy globally today. A vast amount of literature describes the utilisation of biomass in developing countries but the total figure is covered in a dim light. It is however quite clear that a large part of the total energy supply in the developing countries is coming from biomass, of which fuelwood is the most important.

The proportion of wood energy in the total energy supply shows great variation between regions and individual countries: Africa has the highest rate: 50-90%, Asia the lowest: 20-50%, while Latin American countries show large variation:15-95% in different countries. Approximately 20-30% of all primary energy use in developing countries is biomass. The largest consumer of energy is the household sector (approximately 50%) where energy is mainly used for cooking and heating (Gilliusson 1985).

Although the available figures for total consumption of wood fuels are rather uncertain they indicate that the global use of wood as fuel is still greater than the use of wood for industrial purposes. In developing countries about 80% of the total wood harvest is consumed as energy and the remaining 20% is used by industry while in industrialized countries the reverse is true (Goodman 1987).

Thus, to the vast majority of people in the world the importance of wood for energy cannot be overemphasized. A research report on energy policy in Tanzania (Nilsson 1986) comes to the conclusion that "the provision of trees to meet domestic fuel needs must be the principal focus of energy policy outside the industrial fuel sector", and this statement seems to be valid for developing countries in general.

THE WOOD CRISIS

The question has arisen whether or not there is such a thing as a global fuelwood crisis. The causes of reduced availability of biomass are manyfold. They might be ecological, economical, sociopolitical, cultural or a mixture of all, depending on which country is referred to. History shows that wood was in shortage already during medieval times and even earlier in many places. The cause for this was often a privatising of land, where governments or big landlords used the forests for ship building, hunting or other priviligies. The people were not allowed to harvest their day to day need of fuelwood, building material or grazeland, and therefore the pressure on land that was available to them increased. In addition, climatic variation and drought periods contributed to land degradation. Vast areas of deforestated and degraded land still is a reality in many Mediterranean countries in Europe.

Today, the difficulty of separating the cause from the effects and to get a good overall grip of the problems has created a doubt whether the fuelwood crisis is real or fictive. The evidence however, from so many reports all over the world is overwhelming that biomass fuels are used by up to 70% of the populations in the third world , and that locally, shortage is a big problem. Of the 95 developing countries worldwide, 63 are said to be already suffering overall fuelwood shortage and that of these, 34 have no proven gas or oil substitutes (Goodman 1987). It is further suggested that by the year 2000, up to 3,000 million people may be living in areas where fuelwood is scarce or has to be obtained from somewhere else. As it seems, there is no doubt a shortage crisis really exists eventhough the severity varies in different areas.

THE CAUSES FOR WOOD FUEL SHORTAGE

Wherever people live, they demand something of their environment. They need land and water to grow crops and to raise their lifestock. They need trees to build houses, to cook their food and to keep warm. Most of todays shortage of wood fuels in developing countries is quite recent. People old enough to remember 50 years back in time confirm that availability of wood has decreased markedly during the last twenty or so years.

Environmental Destruction

In Africa's arid lands the precipitation has been below the average since more than 10 years back and famine has followed behind it from the savannas of the Sahel through eastern and southern Africa. Environmental destruction is worsened by water stress as a result of bad land use practices. In Latin American countries the big parts of the best soils are owned by a few private landowners who use the land for production of cash-crop for export (coffee, cotton etc). The farmers are then forced to use marginal and fragile soils, often not suitable for cultivation. After a year or two, new land must be sought for or achieved by shifting cultivation. A common response to shortage of pasture land for grazing is to increase the number of animals in the herd which adds to destruction.

Increasing Populations

Rapid population growth and urbanization has been identified as important factors causing the shortage of wood fuel. In Tanzania the "villagisation" (i.e. the population redistribution to nucleated settlements) during the first half of the 1970 ties caused a sudden pressure on land. The access to natural resources, which had been relatively abundant for individuals now became more competitive and scarce in the immediate surroundings of the new homesteads (Nilsson 1986).

The type prospects of population growth in developing countries indicate an increase of 45% by the year 2000. In this case the wood fuel demand will increase by 60% (Goodman 1987). To meet this need, approximately 50 million hectares of fuelwood plantations would have to be established until the year 2000, if these countries are to attain a reasonable degree of wood self-sufficiency (Hosier 1986).

The Economical Situation

Economical factors influencing the shortage of wood fuels is the absence of a stable market. In rural areas, the women and children usually collect the fuel wood from nearby woody vegetation as "free goods" while in urban areas, fuelwood and charcoal are used after being produced in rural areas and transported to the towns and sold. These markets however are usually rather weak. One explanation is that many rural communities do not have a money based economy. Money is very scarce and must be saved for things you cannot get without it. Therefore one must buy the kerosene but the wood can be collected. Analysis of the problem in different countries points towards difficulties to meet the wood shortage at the door, i.e. to start tree planting programmes before there is actually a crisis at hand. As long as you can collect the wood, even though it takes a growing part of your time, the motivation for reforestation is very low for the individual (Bradley et al. 1985).

HOW TO IMPROVE THE SITUATION

Reducing the Demand for Fuelwood

To change the present situation two things must be done, one is to reduce the demand, the other to increase the supply of wood fuel. Cooking with open fires and traditional stoves is the primary end use for fuelwood in developing countries. Recently, major advances have been made in stove technology, thereby considerably increasing the combustion efficiency, as well as in production and dissemination strategies. The cost to provide improved fuelwood cookstoves to the approximately 350 million rural households in developing countries (excluding the centrally planned economies) would cost about $1.8 billion. That is roughly the cost of one standard size nuclear power plant in the United States! (Baldwin 1985).

Chipping and briquetting of biomass as well as pretreatment of hard foods (like soaking) before cooking will also result in more efficient energy use. Alternative fuels like oil products, coal, gas, hydropower etc can be and are used mainly in urban communities but for rural populations there are several limitations. The main obstacles to get access to these fuels are delivery problems and in many cases the lack of a money based economy.

Increasing the Fuelwood Supply

Planting of trees remains the most important activity to increase the wood supply and restore a disturbed environment. The major obstacles so far to reforestation programmes were often caused by a lack of understanding of the social context within which the programmes must be carried out, rather than the lack of technical expertise, equipment or funding. Reforestation projects are more likely to be accepted if they address specific needs that are locally recognised as high priority problems within the society. It is also becoming increasingly clear that reforestation should ideally be part of an integrated land use system including conservation of natural resources.

In rural areas the most important way of increasing the wood supply is to convince the farmers to grow their own energy. Recognition that trees can enhance the fertility of agricultural land and give shelter and shadow to sensitive crops has prompted research on agroforestry and multipurpose production systems. The idea is to recreate systems that resembles the older, traditional agricultural systems where trees and shrubs were abundant on farmed land. It has been calculated that about 300 million hectares of agroforestry could sustainably service roughly 2 000 million people assuming the yield was 5 cubic meters per hectare and year and the requirement was 0.75 cubic meters per person and year. The cost for such a programme would depend on the extent of participation of individual farmers setting up their own agroforestry system (Goodman 1987).

To urban societies, a large part of the energy need would have to continously come from woodfuel and charcoal. A logical solution to create a stable supply situation would be to establish governmental managed large-scale plantations around towns for production of fuelwood and charcoal. However, even in this case, the small holders may have a role to play due to problems of making the large-scale plantations economically viable as they are expensive to establish (Gerden 1989).

WHAT CAN FORESTRY DO?

It is important to stress that a more or less direct application of reforestation methods used in industrialized countries for large-scale plantations, is not always the best way to work. In several cases, woodfuel plantation projects first clear natural ("waste") forest, then establish plantations at substantial costs (promising high returns). An Eucalyptus plantation in Bandia, Senegal was established and produced 1.5 m^3/ha/year. In the same area, an indigenous scrub forest, (Acacia seyal), produced an average of 1-1.5m^3/ha/year with no management and no establishment costs (Gerden 1989)! This way

restricted awareness and knowledge of natural resource management can lead to replacement of natural diversified forests with monocultures, often exotic species. The importance of increased research concerning the productivity of indigenous species is obvious.

However, as the overall support for forestry has increased in both aid agencies and the governments of the developing countries themselves, tree planting projects today are often better matched to the local environment and the needs of the rural communities. The importance of involving local people in project planning, seedling production, etc as well as establishing the ownership relations before the project starts is evident.

Reforestation Methods

Reforestation can be done in many different ways depending on the local need and the site conditions. The production systems most frequently encountered for improving the life conditions and restore the environment in and around rural societies are: soil conservation systems, multipurpose tree production, agroforestry and industrial plantations. The design of these production systems must be built on an understanding of long-term sustainability of a site (Shen 1989). The physiological requirements of the different plant species as well their interaction with each other and the environment must be considered. Equally important are considerations of social and cultural issues.

Biological Engineering

Water and nutrients are usually the critical resources for production systems in a deteriorated environment. A combination of species selection (drought resistent, nitrogen fixing spp) and micro-tophography engineering (contour-ditches, hedgerow-systems, terracing, water collection damms etc) can successfully improve yield and help restore productivity. The varying root structure of plants are important characteristics for selection of species for different sites and purposes. The water availability at a site can be improved by using plant species with deep root systems. When soil moisture increases (due to favourable micro-climate from established vegetation) species with more shallow roots can survive.

The contour-hedgerow system being designed for the midhills of Nepal and North Eastern China are good examples of actual design to achieve a number of goals (Shen 1986). The soil conservation program in the severly eroded Loess Plateau in

north central China are other examples of multidiciplinary cooperative projects trying to overcome drought, nutrient insuffiency and a severe erosion by using complementary methods (Sennerby-Forsse et al. 1989).

Agroforestry generates a variety of model systems for multi-purpose land use. Cultivation systems including crop-Pawlonia interplanting in China (Zhu Zhaohua 1989), alley cropping with cereals and legumes alternated with nitrogen-fixing trees and shrubs i Nigeria (Goodman 1987), line-plantations with timber/fuelwood species like Grevillea robusta or fruit trees combined with crops, or borderline trees or bushes (Euphorbia, Commifera, Tamarindus indica etc) which serve as property markers while providing fuel and other products, in arid areas of Africa (Weber 1986) are interesting and promising agroforestry techniques.

Research and Development Needs

One particular area of interest to fuelwood plantations is the maintenance of the production. These trees and shrubs should survive repeated harvesting of woody components. Many species have the capacity to regenerate new growth after being cut. This capacity is particularly valuable in arid areas where establishment of new plants is difficult. The harvesting methods and the timing of harvesting influences the sprouting of new shoots from stumps, roots or branches and research is needed to determine the optimal cutting period for different species.

A number of harvesting methods are known to allow regrowth after harvest, like coppicing, pollarding, lopping and pruning. Of these, coppicing is the most widely used. Cutting is done at the base of the plant and new shoots emerge from the stump or roots. Many species can stand several rotations of coppicing provided that they are cut during the dormant stage. A well fed root system is of vital importance to start the new growth during the following vegetation period. Besides being very valuable for fuelwood production, coppicing also increases the effectiveness of windbreaks (through cutting, the number of shoots increase, making the shrub more dense). The Salicaceae, i.e. poplars and willows, are well known representatives of coppicing species which have been widely used in most parts of the world for a variety of uses since ancient times (Zsuffa et al. 1990). The national energy forestry programme in Sweden relies on a coppice production system with fast-growing willows to produce biomass for energy (Siren et al. 1986a).

Although wood production for energy has been investigated for several years and much experience of trees and shrubs exists in local populations, there is still a lot to be learned. A proposal for future work was summarized in a paper presented in

Working group P1.09-00 at the 18th IUFRO World Congress in 1986 (Siren et al. 1986b). The research proposed is of high relevance to reforestation efforts in the developing countries and are in short: to increase knowledge regarding species/site interactions i.e. to understand how tree species interact with their environment, to select and breed for superior planting material, both indigenous and exotic species, to develop appropriate management procedures for different production systems and to construct and test mechanical equipment for harvesting and handling of wood in both large-scale plantations and for smallholders.

Furthermore, to provide useful advice and strategies for improving the present situation of both food and fuelwood shortage as well as environmental degradation in developing countries, foresters must learn to match trees to food crops and to consider cultural needs. At last but not least, to succeed in their undertakings, they must consider predispositions and idiosyncracies of rural communities.

CONCLUSIONS AND RECOMMENDATIONS

Forestry has a major responsibility to recognize the problems of tree shortage, for fuelwood production and/or for environmental protection, in developing as well as in industrialized countries.

The recommendations for future undertakings from IUFRO group P.1.09.00 follows the outline which resulted from the workshop in Beijing 1988 (Eds. C.P. Mitchell et al. 1989). The focus is on the development of model systems for multipurpose tree production systems. To achieve this it seems necessary to establish a framework, to define the relevant criteria for different production systems and to develop methods for exchange of knowledge and experience between regions with similar problem. However, foresters can not solve the problems alone but should cooperate in multidisciplinary projects to diversify land use in regions with a degraded productivity.

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FOREST WEED MANAGEMENT : RECENT DEVELOPMENTS IN FRANCE AND GERMANY

Henri FROCHOT, Achim DOHRENBUSCH and Horst REINECKE

- I.N.R.A., Station de Sylviculture et de Production Champenoux, 54280 SEICHAMPS, France.

- Institut für Waldbau der Universität Göttingen Büsgenweg 1, D-3400 GOTTINGEN, FRG.

- Niedersächsische Forstliche Versuchesanstalt Grätzelstrasse 2, D-3400 GOTTINGEN, FRG.

INTRODUCTION

The success of forest regeneration either by sowing or by planting depends on monitoring of spontaneous vegetation. It requires a lot of work, with manual, mechanical, chemical or other equipment. The effects of vegetation on young trees are unsufficiently well known for a adequate management of equipment.

We will briefly expose the problem, then give a few results about the effects of vegetation on young forest trees and some example of natural regeneration and plantation strategy.

GENERAL

France, and to a lesser extent Germany, present very diverse forest landscape on a comparatively small area : plain forest, hill forest or mountain forest ; wet zones or dry plateau ; different rocks and soils ; continental, oceanic, mediterranean or mountain climate and all the intermediaires. Forest species are also very numerous. The most interesting are among hardwoods : sessile, pedunculate and red oak, beech, ash, maple, wild cherry, black and hybrid walnut, poplar, chesnut tree, mountain ash. Among conifers : silver fir, Douglas fir, Norway and sitka spruce, Austrian pine, scotch pine, cluster pine, Aleppo pine, cedar, european and japanese larch.

The natural regenerations should be favorised if possible ; especially on sites convenient for sessile and pedonculate oak, beech, silver fir, spruce, scotch pine, as well as for sparce rare hardwoods. The canopy opening, necessary for the regeneration development, favorises the spread of sponta-

neous forest vegetation. First species to develop are perennial monocotyledones : graminees, joncacees and cyperacees. Bramble and bracken are also frequent species found in oak and beech regenerations ; they cover important areas in France. The woody species are present as shoots or occurs by natural sowing in regenerations .

When natural regeneration is not possible, plantation is the most common method used. The costs can be lowered by partial planting in pre-existing poor stands, which requires individual tree treatment. But the most common method is certainly plantation after clean felling which is either followed or not by stump removal and soil works. Bare rooted plants are generally used, hand planted or sometimes planted by planting equipment.

These techniques cause a fast development of diverse vegetation, in which perennial forest grasses often occupy the largest areas and quickly colonize all free space. Some other species may also massively colonize the ground : some herbaceous broadleved species as thistle, bracken, or small sized shrubs such as bramble, raspberry, heather, broom, furze. Woody species generally come later.

Reforestation of sites recently abandonned by agriculture may also be mentioned. Such places have the highest degree of artificalisation of forest conditions. On such sites, ready for plantation, flora was reduced through agricultural treatment. After that the plantation site is colonized by annual land species, then by perrenial species excluding woody species. Fertility of such soils frequently causes a very strong development of vegetation.

EFFECTS OF COMPETITIVE VEGETATION ON FOREST PLANTS

In the very complex ecosystem forest, relations between the individuals of ecosystems exit during the whole life time. Normally during the first phase of development of a stand it is the interspecific competition, that means the struggle between different species, which influences the selection. Later the density of the stand is reduced through the intraspesific competition, which means the competition within a particular species. The plants compete when because of their growth the available water and nutrients reserves as well as light conditions are inadequate to garantee each individual an optimal growth (ROHRIG, 1980).

It is more or less irrelevant whether the forest has been established by natural or artifical regeneration. Even though the natural regeneration under a shelter offers mostly much better manipulation possibilites : with a well made silvicultura canopy the light conditions and therefore other ecological factors like radiation balance and precipitation can be manipulated so that the competition conditions are not moved automatically in favor of the competative vegetation. The conditions after artifical regeneration through a clear cut are usually less suitable : through the sudden, radical change of conditions the fast developing vegetation reveives a tremendous competition advantage.

The interspecific competition with which we are concerned with in forest plant communities the following forms of interaction are possible (ROHRIG 1980, FROCHOT 1990) :

- **struggle for the growth factors**, especially light, water and nutrients. It is often surprising to see how on clearcut areas even a accompanying vegetation which appears to be scarce has a tremendous shading effect on the regeneration under cover. In investigations of the natural regeneration of oak it could be shown that under a light shelter of the herb **Senecio fuchsii** the light intensity was reduced by 50 % (DOHRENBUSCH 1990). This caused unwanted conditions which were supposed to the prevented through the extreme clearcut treatment. In the case of more dense and more richly varied plant population the light conditions are even less intense and especially the existence of grass and shrubs has a negative influence on the water supply.

In experiments where the influence of weeded areas on young trees was tested, it could be shown that the growth of young trees was correlated with the surrounding competitive vegetation. Areas of **Festuca pratensis** or **Agrostis stolonifera** caused a growth reduction of about 30 % with oak and Scotch pine and 50 % with poplar (FROCHOT 1990). In additional soil water measurements the effect "water competition" proved to be the most important factor for this phenomenon.

Other investigations combinating herbicides, plastic mulch and fertilizer, showed the same effect on oak and wild cherry, namely a strong inhibiting influence through water competition but no influence through nutrient competition (LEVY et al., 1989).

- **physical effects of the plants** on each other, in the root space but also overground, for example through expanding growth, overlaying and through intensive rooting of the upper soil layers. Very strong physical effects of the plants on each other can be especially observed on grass species. **Molinia**, **Calamagrostis**, but also **Deschampsia** are well known for their dense rooting.

Investigations in pine-forests on poor sites with a dense vegetation of **Deschampsia flexuosa** showed that a natural regeneration of pine is impossible without opening the mineral soil by removing the grass. Above the mineral soil, the grass has a root layer of about 6 cm. Here the root biomass can reach up to 40 mg/cm3. Also within the actual mineral soil, high values of living biomass values can be expected. This is especially valid in the relatively densely rooted layer down to a depth of 8cm, below that the root intensity decreases rapidly.

In addition to these root effects on the young seedlings, **Deschampsia flexuosa** also bears a another great risk for the young forest plants. When in autumn hundreds of flowering stalks on each square meter lay down on the ground, covery during the whole winter season the young trees and increase the risk of infections.

- **Effects of metabolic products** (allelopathy) wich are secreted from dead or living plant parts. Phytotoxic effects of allelopathic substances may cause disappearance of natural regeneration or stagnation of growth of seedlings, as silver fir seedlings with **Festuca silvatica**. The negative effect can be directly observed on the young trees or indirectly through the microflora or the mycorhiza status, for example the effect of heather on Norway spruce. Several forest grass are suspected to produce phytotoxic allelopathic substances, but it is difficult to demonstrate the real impact in forest conditions on account of interactions between water, light or nutrients.

So the inhibitory effects of allelopathic substances on **Molinia coerulea** and **Carex brizoides** had be proved in laboratory investigations. BECKER (1984) carried out experiments on old oak stand with canopy : the depot of fresh leaves of both grasses reduced by half the survival of oak seedlings in regard to control with inactive dry leaves. The inhibitory effect was increased with reduction of relative lighting.

Other secreted substances can have positive effect : what is the real effect of carbonaceous or nitrogenous components in interacting processes ? It is insufficiently known.

- **Microclimatic effects** induced through the structure of vegetational surroudings. The development of aerial parts of neighbouring plants cause modifications in air circulation, carbonic dioxide, water vapour, thermic layers and light energy. The balance between the respective size of the plants and young trees, their proximity and density of aerial parts induce determinant but less known relations. Unfavourable effects from the light reduction are opposed to favourable effects through reduction of evapotranspiration and through protection from frost (AUSSENAC, 1976).

So in an experiment with scots pine the young trees did not overtop the level of grass during the first year. During this time the growth was improved through the existance of grass, but providing that a small weeded area was maintained between the young trees and grass (FROCHOT and TRICHET, 1989). That positive effect was improved to favour the combination of the two opposite effects : reduction of water competition through weeding around the tree and reduction of evaporation caused by the protecting effects of vegetation shelter. In this case the growth advantage was very small. But the protecting effect can have more important practical interest with less water demanding weeds, as with several annual herbaceous plants in first years of plantation or controlled woody weeds preserved in older plantations.

- **Indirect effects.** Certain plant species have an indirect influence on others through inhabiting pests (for example dense grass areas in young deciduous tree stands better the life conditions for bark-and root eating mice species).

The competition phase in primary stand growth has been for a long time

unsuffiently observed. WALTER (1960) remarked that the natural occurance of plant species is seldom directly determined by the site conditions but by the existence or non-existence of competing species. The site conditions themselves only change the competition conditions and therefore influence only the spread of the species indirectly.

ELLENBERG (1952) has shown for many species through numerous experiments that the physiological behavior, which means the reaction of the isolated plant on site conditions, and the ecological behavior, which means the growth under the influence of the competitors, is different. Often plants retreat through the pressure of the competitors from the area of their physiological optimum and are forced to inhabit sites, where the pure physical site conditions are less suitable.

STRATEGIES OF WEED MANAGEMENT

PREPARATION OF PLANTING SITES BEFORE REFORESTATION

The preparation of reforestation areas is determined by the mature stand, the area conditions, the topography and the selected tree species. These main conditions determine the intensity of the treatment for mechanical and chemical methods.

Normally the stand establishment by natural and artifical regeneration on large areas is made without site preparation. Well-established perennial plants species will have "explosive" development after cutting the canopy. Those plants will not can be controlled by chemical methods after stand establishment because effective herbicides are not selective on forest plant when applied on the foliage. Therefore these should be eliminated from the felling area before it is cleared. Herbicides with a specific effect on the vegetation and with no long-term effect on the soil should be favorised (asulame, glyphosate, triclopyr, MCPB, 2,4-D, fosamine ammonium). Herbicides are chosen according to one or some species which can have a negative influence on the futural regeneration.

If a mechanical preparation or the cutting of vegetation is necessary, herbicide should be applied several months before the work begins, in order to have sufficient time before the physiological action damages the plants.

Utility of mechanical soil preparation is judged advisable or not according to the situation. In weak soil intensive site preparation can cause, beside nutrient losses, a destruction of structure and a reduction of porosity, leading to disturbences in the hydric supply and roots function. That is for example the case for superficial hydromorphic soil, where mechanical preparation has a negative influence on the growth conditions for the forest plants.

Site preparation can be necessary to better the physical soil conditions by loosering compact soils and by breaking dense layers. On poor sites it can be useful to displace the nutrient supply (P_2O_5).

Superficial preparation is also useful to disperse thick humus layers and to drain sites with unfavourable ground water conditions.

Mechanical site preparation is not effective to eliminate established perennial vegetation. On the contrary soil breaking can cause development of competitive plant species such as grasses, heather, broom ..., which are still favorized by fertilization. Therefore when mechanical preparation is necessary, it can be useful to combine them with chemicals or other methods.

Complete site preparation make cultivation possible or more easy. But radical treatments are not necessary neither useful.

Partial site preparation can be sufficient and preserve the life conditions for the accompanying vegetation.

STAND ESTABLISHMENT

- Intensive cultivation

This method is selected to obtain a good establishment and a maximum initial growth. It is useful mainly for fast growing forest species in favourable soils. Complete site preparation has positive influence on the growth of young trees providing that vegetation is eliminated at least at the proximity of forest plants. Otherwise favourable effects of fertilization and preparation are profitable to vegetation, which will be then more competitive for water and damaging for plantation. Low persistant herbicides (simazine, atrazine) applied just after planting can guard ground weeded during the firt growing season. Generally one other treatment is still required during second or third year to control various vegetation with large effective herbicide applied on plant rows or on all stand areas (hexazinone, glyphosate).

Here chemical replaces tillage which generally injures roots of young trees and can not control vegetation on the plant line.

- Competive replacement

Plantations can be often made before the accompanying vegetation has occured, especially after felling, after complete site preparation, after weeding with non persistant herbicide or on former agricultural used areas. In thoses cases it is useful to seed plant species which are normally used agriculturally (competive replacement). The presupposition for this method is an exact soil analysis to equalize nutrient losses. These agricultural plants store the nutrients which later garantees sufficient nutrition of the forest plants. Seed mixtures of these agricultural plants can be selected for different site and vegetation problems. The plant cover exist normally for a three years period, after that it will be replaced by the natural vegetation. Normally under the climatic conditions of central Europe one can be shure that the plantation is stable after this time.

- **Mulching**

Another method in order to protect forest plants is the total or partial covering of the ground with biomass (straw, bark, grass) or materials which have been produced directly for these purposes (foil, plates). These treatments are not applied during the vegetation period. The growth of the forest plants increases, mainly on account of evaporation reduction from the ground. Fertilization can be especially profitable because the young tree has a better hydric alimentation. This method is useful after complete site preparation. Incidences of animals, small gnawing or big mammals, have to be taken into consideration.

- **Conservation of selected accompanying vegetation**

The biggest spontaneous forest species has only a temporal or spatial limited negative effect on forest plants. Well controlled accompanying vegetation can be use to improve the form of young trees, to protect them against damages from mammals or to prevent the spreading of more competive vegetation. The specific elimination of damaging perennial species must have been made by chemical method before reforestation (above-mentionned).

After stand establishment the main problem is generally with grasses which have to be controlled. The elimination of the above ground biomasse through cutting will increase their growth. An application with selecting herbicides (propyzamide, dalapon) is better than mechanical methods : several selective graminicides can be used at different seasons. With foliar graminicides (as fluazifop-butyl) the application can be made during the growth without damage on the forest plant. So we have opportunity to select the time of season when the best effect on the competive vegetation is expected.

Broadleves species are favorized by grass control. Somes damaging forest plants can occur and spread out too quickly (broom, bramble, heather ...), requiring selective treatment with appropriate herbicide. But generally, when accompanying shrubs appear, only few treatments consisting of a partial cutting around the forest trees, or through chemical sprays inducing shrub nanification are needed.

CONCLUSION

Range of possible weed strategies in forests is large. Choosing one of them in given regions depends on site conditions, economical background and production objectives as defined by public or private forest organisations.

Technical knowledge and availability of equipment is not sufficient for an optimal used of weed management strategies. When using chemical methods, one faces attitudes of suspicion from forest managers, which are often enhanced by pressure of other opinion groups.

Better knowledge of effects of accompanying plants is necessary to govern the choice between strategies. Research results give clear informations on possible influence on growth factors : negative effects due to competition for water, light and nutrients ; negative effects with allelopathic substances and physical damages ; positive effects with favourable substances and microclimate improvement due to plant shelter. These effects are positive or negative depending on microenvironment of forest trees and on site conditions.
It is therefore difficult to generalise experimental results. Further research has to be conducted in order to assess the impact of accompanying vegetation on young forest plantations and to explain main competition processes.

Weed management strategies must be compared in defined situations to estimate :

- performance of treatments in the development of plants ; mainly growth, form acquisition, root establishment.

- global economical value of treatments, including impact of animals and pests.

- biological evaluation of indirect positive and negative effects of treatments, including : disturbances created by soil preparation ; introduction of molecules irrelevant to ecosystem (herbicide, plastic) ; modifications of forest flora, soil and animals life.

It is necessary to ensure a broader diffusion of often confidential informations about biological effects of herbicide treatments which are still poorly known. Finally it should be the aim to obtain new data in European forest conditions.

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RESUME

Gestion de la végétation forestière : évolution en France et en Allemagne.

La France et l'Allemagne présentent des paysages forestiers particulièrement variés. Relief, roche-mère, sol, climat, antécédents, espèces forestières, mode de régénération, techniques de reboisement, composition de la flore spontanée, y sont très diversifiés. La végétation spontanée, favorisée par les opérations de reboisement, devient alors le problème essentiel des jeunes peuplements forestiers.

Différentes formes d'interaction s'établissent : la lutte pour les facteurs de croissance, lumière, eau et éléments nutritifs ; les effets physiques entravant le développement des racines ou de l'appareil aérien ; la sécrétion des produits métaboliques pouvant avoir des effets inhibiteurs (allélopathie) sur les jeunes plants ; les effets microclimatiques induits par la structure de la végétation, positifs (effet abri) ou négatif ; les effets indirects.

La lutte contre les espèces pérennes qui auraient un effet négatif pour le futur peuplement, est entreprise en préparation (c'est-à-dire avant reboisement) chaque fois que c'est possible. La méthode chimique est préférable, sauf si les conditions de station rendent nécessaire une préparation mécanique. Une préparation partielle est parfois suffisante. Différentes stratégies sont utilisées après installation du peuplement : l'entretien intensif avec les herbicides sélectifs appropriés ; le remplacement de la flore défavorable par des espèces annuelles de couverture ; les paillages divers ; la conservation d'une végétation spontanée sélectionnée, servant d'accompagnement végétal.

La gestion raisonnée de la végétation forestière nécessite de mieux connaître les interactions entre végétaux, et l'impact global des stratégies utilisées.

USE, FATE, AND RISK ASSESSMENT OF FORESTRY HERBICIDES IN THE SOUTHERN UNITED STATES

Jerry L. Michael and Daniel G. Neary
Research Ecologist and Research Soil Scientist
USDA Forest Service
Auburn University, Alabama and University of Florida, Gainesville, Florida, USA

and

Dean H. Gjerstad and Peter D'Anieri
Professor and Research Associate
School of Forestry, Auburn University, Alabama, USA

SUMMARY

A review of the use, fate and environmental risks associated with use of glyphosate, hexazinone, imazapyr, sulfometuron methyl, and triclopyr in pine silviculture in the southern U.S. is presented. Herbicides are widely used in planting site preparation, weeding, and release (cleaning and liberation) because they usually are less expensive, result in less environmental disturbance than heavy mechanical methods, and are often the only viable option because of terrain. Mixtures of herbicides are sometimes used to cover a broader scope of target vegetation.

Herbicides used in forestry contaminate surface waters to varying degrees according to the application rate, method of application, product formulation, and site specific characteristics. Highest concentrations are observed in streams in pulses of short duration during the first two or three storm events following application and then stream contamination rapidly declines. Persistence of herbicides on treated sites is affected by many factors. Half-life in vegetation is usually <40 days and from 7-180 days in soil.

Environmental Impact Statements and Risk Assessments are reviewed for the southern U.S. It is concluded that 1) other methods of vegetation control pose greater health risks to workers than herbicides, 2) the herbicides evaluated met acceptable risk standards for terrestrial and aquatic wildlife when applied at typical rates using current methods, 3) care needs to be taken with herbicides concerning threatened and endangered species, 4) herbicides do not adversely affect soil productivity and actually protect it by reducing compaction and erosion, and 5) low application rates and mitigation techniques such as buffer strips result in only a very slight risk to water quality.

Keywords: Human health, exposure, toxicity, wildlife

INTRODUCTION

Silviculture is practiced more intensively in the southern U.S. than in any other region of North America. Favorable terrain and climate make natural and artificial regeneration of pines a widespread practice throughout the region. Selected hardwood species are regenerated artificially on a limited basis, and natural hardwood regeneration is essentially not managed. Site preparation, weeding, release, fertilization, and thinning are commonly applied to pine stands. Herbicides are used extensively in the site preparation, weeding, and release operations that may be employed in pine regeneration. Herbicide use is comparatively minimal in hardwood regeneration, and the following review only addresses herbicides as they pertain to stand establishment techniques in pine silviculture.

Increased citizen awareness of the use of synthetic chemicals in food and fiber production has increased public concern for environmental safety. All herbicides must meet registration requirements set by the U.S. Environmental Protection Agency (EPA). Environmental fate studies characterize the movement and disappearance of the chemical within and from the forest environment. Risk assessment then evaluates the data on toxicology and environmental fate to determine whether the chemical is suitable for use. While there are many herbicides available for use in forestry sites (i.e. amitrol; asulam; atrazine; bifenox; bromacil; 2,4-D; 2,4-DP; DCPA; dalapon; dicamba; diphenamid; diuron; fosamine; glyphosate; hexazinone; imazapyr; napropamide; oxyfluorfen; picloram; simazine; sulfometuron methyl; tebuthiuron; and triclopyr) space limitations preclude complete coverage in this paper. Therefore we will review the extent of silvicultural herbicide use in the southern U.S., environmental fate, and the subsequent risk assessment process. Only the most important forestry herbicides registered by the EPA over the last 15 years (i.e. glyphosate, hexazinone, imazapyr, sulfometuron methyl, and triclopyr) will be reviewed.

SILVICULTURAL HERBICIDE USES IN THE SOUTHERN U.S.

The region included by this review is that area encompassed by the range of the southern pines, i.e. loblolly pine (*Pinus taeda* L.), slash pine (*P. elliottii* Engelm.), longleaf pine (*P. palustris* Mill.), and shortleaf pine (*P. echinata* Mill.). The commercial southern pine region stretches from Maryland, south to central Florida, west to eastern Texas, and north to southern Missouri.

Major physiographic provinces within the region are the Lower Coastal Plain, Upper Coastal Plain, Piedmont, and Interior Highlands (Walker 1980). Differences in physiography and associated competing vegetation among these provinces, as well as ownership patterns and management philosophies, are the basis for differences in forest herbicide use opportunities and practices.

A. Site preparation

Site preparation is defined as removing unwanted vegetation, slash and even stumps, roots and stones from a site before afforestation or reforestation (SAF 1983). In the southern U.S., this has been accomplished using a large crawler tractor equipped with rolling drum choppers, shearing blades, V-blades, or root rakes for debris removal. Bedding, discing, ripping, and subsoiling are common mechanical techniques for tillage. The debris removal and tillage operations are prescribed in numerous combinations. Burning is a comparatively low-cost technique for debris removal that is often employed in conjunction with, or in substitution for, intensive mechanical methods.

Herbicides have come into favor to replace mechanical site preparation because herbicides suppress hardwoods and herbaceous weeds better, create less erosion potential, and cost less than all but burning and the lowest-intensity mechanical techniques. Hardwood suppression with herbicides is superior to mechanical methods because the herbicides used affect the target root systems. Only the most intensive and therefore expensive mechanical methods effectively treat the target root system, and these methods result in more abundant weed seed germination, faster herbaceous weed colonization, and greatly increase erosion potential through the exposure of mineral soils. Weed suppression is superior with herbicidal site preparation because the chemicals used are directly phytotoxic to a broad spectrum of weeds, do not disturb the ground resulting in lower erosion potential, and avoid rapid germination and establishment of the herbaceous community. Except for the Lower Coastal Plain, most pine sites in the South are on sufficiently hilly terrain for substantial erosion losses to occur, and many are prohibitively steep for safe tractor operation. Herbicides, which are frequently applied by helicopter, allow foresters a silvicultural option otherwise unavailable for these sites. Herbicidal site preparation is less prevalent in the Lower Coastal Plain, because bedding is necessary for plantation establishment on most sites.

The major attribute sought in a site preparation herbicide is a broad efficacy spectrum. Site preparation is accomplished with several herbicides: glyphosate, hexazinone, imazapyr, and triclopyr. Picloram and 2,4-D are also widely used, but are not the focus of this review. All of these chemicals weakly control certain species, so species composition is an important prescription criterion. Optimum treatment efficacy occurs at different times of the year for these chemicals allowing site preparation to be done throughout the summer. Hexazinone is readily adsorbed by soil, so rates must be prescribed carefully, using higher rates on fine textured and highly organic soils. Mixtures of herbicides or surfactants with imazapyr are being tested to speed up desiccation for prescribed burning and to increase the spectrum of controlled species. Herbicidal site preparation is augmented by burning the treated stand approximately 6-12 weeks after spraying to facilitate planting the following winter. Although conventional practice is to ignite as hot a fire as possible (in both herbicidal and mechanical site preparation), this may not be desirable due to increased site disturbance and potential soil and nutrient loss.

B. Weeding

Weeding is defined as "a cultural operation eliminating or suppressing undesirable vegetation, mainly herbaceous, during the seedling stage of a forest crop and therefore before the first cleaning, so as to reduce competition with the seedling stand" (SAF 1983). In the southern U.S., foresters generally use the terms "herbaceous weed control" or "herbaceous release" as synonyms for weeding. Weeding is practiced almost exclusively in plantations at the beginning of the first growing season. Herbicides are applied either by tractor-mounted boom sprayers in a one- to two-meter wide band centered along the seedling row, by backpack sprayer in a circle or square of similar width centered over individual seedlings, or aerially.

Weeding is most prevalent in bedded plantations of the Lower Coastal Plain. Bedding is necessary on many such sites to form a planting spot above the standing water, which commonly persists through the winter planting season. However, bedding promotes a dense and vigorous weed community as a result of soil seed bank disturbance and exposure of mineral soil for newly-disseminated seed. On upland sites, weeding has been less readily adopted, but likely provides comparable benefits. Weed control can improve survival by 20% or more (Creighton et al. 1987), particularly on droughty sites or in dry years by reducing water stress. Longleaf pine emerges from the grass stage much more rapidly in weeded stands (Nelson et al. 1985).

Weeding is accomplished chiefly with sulfometuron, while glyphosate, hexazinone, and imazapyr are used to a lesser extent. Applications are made pre-emergence to early post-emergence (March-June) depending on the chemical, at rates approximately one-fourth of site preparation rates. Because glyphosate must be used post-emergence, pine seedlings have already experienced some competiton and are susceptible to glyphosate injury. Glyphosate is the most effective herbicide on Andropogon spp., which are abundant on pine sites throughout the region. Hexazinone is usually tank-mixed with sulfometuron to broaden the spectrum of weeds controlled. Pines respond positively to weeding with imazapyr as well, but the benefits may be tempered by application-rate dependent stunting of height growth in the seedlings. Current tests will have to be followed further to see if this trade-off warrants use of imazapyr for weeding.

C. Release

Release operations are defined as those that "free young stands of desirable trees, not past the sapling stage, from the competition of undesirable trees that threaten to suppress them. Distinction may be made between two types of release operations, cleaning and liberation, which differ mainly as to the ages and sizes of trees eliminated" (Smith 1986). Cleaning is defined as removing trees, in a seedling or sapling stand, "to free the best trees from undesirable individuals of the same age that overtop them or are likely to do so" (Smith 1986); when the trees removed are older than those released, the term "liberation" treatment applies (SAF 1984).

If needed, release is generally practiced once between years one and

five of crop development. Release decisions are based on factors such as hardwood size and density, site quality, stand age, cost, and anticipated effects of cleaning on rotation age, stand structure, and yield. Greatest benefits are obtained by treating sites with the most hardwood sprouts, on the better sites, and at a young age.

Glyphosate, hexazinone, and imazapyr are used for release in the southern U.S. Hexazinone is used early in the growing season, while glyphosate and imazapyr are applied at the end of the growing season. Rates employed are approximately one-half of those used for site preparation. Glyphosate is often effective, but inadequately controls several hardwoods. In addition, the last flush of pine growth is often killed by glyphosate. Hexazinone inadequately controls some of the same species as glyphosate, and often kills pine seedlings. Hexazinone should not be applied unless pines average at least two meters tall. Prescribed rates must also carefully consider soil texture for best results. Imazapyr is the most promising compound for release because it suppresses the broadest spectrum of common southern hardwoods. Although some stunting symptoms may appear just as when using imazapyr for weeding, this is of shorter duration in applications to 2- to 4-year-old trees.

FATE OF HERBICIDES IN THE ENVIRONMENT

An understanding of the fate and movement of herbicides and their residue times in the forest ecosystem is essential to a meaningful evaluation of potential ecosystem risk from herbicide exposure. Studies conducted in southern U.S. forest ecosystems have attempted to quantify the residue times of several of the most commonly used herbicides, and determine their movement offsite in runoff.

The disappearance of herbicides applied to forestry sites can be described in terms of fate processes which dominate disappearance from plants, litter, soil, and water. Disappearance may occur via photodegradation, hydrolysis, volatilization, plant and microbial degradation, leaching, and runoff. The dominant fate processes vary according to the chemical characteristics of each herbicide, ie. glyphosate, microbial degradation; hexazinone, plant and microbial degradation; imazapyr, microbial and photodegradation; sulfometuron methyl, acid and photo-catalyzed hydrolysis; triclopyr, photolysis and microbial degradation. Volatilization is not a dominant fate process for any of the above herbicides because of their very low vapor pressures. Volatilization can, however, be a minor route in the disappearance of the ester formulations of triclopyr.

Herbicide disappearance from forestry sites is a function of many physical, chemical, and biological processes. Herbicide is first intercepted by vegetation, exposed litter, surface water when it exists, and exposed soil. Mass transfer of herbicide occurs among the various matrices by physical displacement of surface deposits, washoff, leaching, and storm runoff. Physical mass transfer, then, is principally driven by precipitation and wind conditions. Chemical and biological processes are kinetic processes which can be described by rate constants. Rate constants are determined for a given reaction under specific conditions of heat,

hydration, light (quality and quantity), pH, concentration of reactants, and presence or absence of other catalyzing agents. Thus site-specific characteristics of temperature, composition of the reaction matrix (soil type, plant species, water quality), moisture, pH, and light are very important in determining rate of disappearance of applied herbicides.

Herbicide disappearance from treated sites somewhat approximates a logarithmic decay similar to that of a first-order chemical reaction. Use of half-life to describe the rate of disappearance has therefore been adopted by environmental scientists. Because of its popular use and the lack of a better term, we will continue the use of half-life in this paper as a measure of residue time in soil and plant tissue, but do not intend such use to imply first-order kinetics for disappearance from field locations.

A. Water

Herbicides and their breakdown products are transported within ecosystems mainly via the water cycle. Precipitation and evaporation are the principal driving forces in the processes of runoff and leaching and interaction of these driving forces with other site specific characteristics greatly affect potential stream contamination.

Herbicides broadcast-applied to forest sites contaminate surface waters to varying degrees. There is a positive correlation between the applied rate and application method, and maximum observed surface water concentrations. In general, surface waters are more likely to be contaminated by aerial applications and least likely to be contaminated by stem injection. Soil spot treatments result in only slightly higher levels of contamination than those observed with stem injection. Product formulation also affects contamination, with pelleted formulations contributing more to streams than when the same herbicide is applied as a liquid if the herbicide is one which may be bound to soil particles. Herbicide movement into streams occurs principally during the first 2-3 storm events. Maximum stream concentrations tend to be associated with peak stream discharge but may be less than 15 minutes in duration (Michael 1986, Michael and Neary 1987). Under conditions observed in the southern U.S., the principal mechanism for stream contamination other than direct input during application appears to be short distance overland or subsurface flow, the effects of which can be mitigated through use of untreated streamside buffer zones (Michael 1986). Contributions to stream contamination by short distance overland flow are particularly important in predominantly clay soils which have water infiltration rates <1.5 cm hr^{-1}. Storm events during seasons of herbicide application in most areas of the South frequently exceed 2-5 cm hr^{-1}.

B. Plants

The magnitude and duration of residues in plants is important in determining potential risk. The most significant exposures of terrestrial and aquatic animals to herbicides in forestry operations is by direct contact during application or by contact with or ingestion of contaminated

water and plant tissues. Animals feeding on recently sprayed vegetation would be at the greatest potential risk of acute poisoning, while those feeding on vegetation containing residues of previously applied herbicides would potentially be at risk from chronic poisoning.

Studies conducted in the southern U.S. to determine plant tissue herbicide residues are limited in number and scope, but in general half-lives do not exceed 40 days in plant tissue and residue levels are species and application-rate dependent. Hexazinone, when applied at 1.7 kg ai ha as a spray resulted in half-lives ranging from 4-15 days on five different species (Michael et al. 1990). Imazapyr persistence in composited vegetation following application of 2.2 kg ae ha^{-1} had a half-life of 12-40 days (Michael 1986). Studies of sulfometuron methyl persistence in Mississippi and Florida showed half-lives ranged from 1-5 days for the 9 species studied (Michael and Neary 1987). Glyphosate and triclopyr persistence in plants has not been studied in the South but in a study from Oregon, glyphosate half-life was 10-27 days (Newton et al. 1984) and triclopyr half-life is reported to be <7 days in grasses in the western U.S. (Norris et al. 1987; Whisenant and McArthur 1989). In woody stems, glyphosate could be expected to remain much longer because it is not metabolized by plants (USDA 1984).

Plant tissue residues are usually highest immediately after application and decline very rapidly for the first few days following application indicating possible mechanical loss from foliar surfaces (Michael 1986, Norris et al. 1987). Rapid translocation to underground plant parts may also contribute to the observed short half-life. Maximum observed plant tissue concentrations in field studies ranged from 15-130 mg kg^{-1} (based on plant tissue fresh weight) for each kg of active ingredient applied per hectare (Michael 1986, Michael and Neary 1987, Michael et al. 1990).

C. Soil

Herbicides appear in litter and soil immediately after application, but residue levels usually continue to increase for several days before beginning to disappear. Initially, interception by vegetation accounts for most of the applied herbicide. Only exposed litter and soil receive herbicide directly at the time of application. Through-put and physical displacement result in additional soil and litter contamination within a few days of treatment. Washoff from precipitation events and translocation to underground plant parts possibly resulting in root exudation accounts for the remaining early inputs. Subsequent additional inputs result from leachate from leaves and leaf fall which contributes to the litter layer. Once in the litter and soil, herbicides may be leached, move downward and laterally via macropores, be redistributed and cycled via plant uptake, and degraded principally by microorganisms and hydrolysis. Microbial population density and factors which affect microbial activity strongly affect herbicide persistence.

Metabolites and hydrolytic by-products have been identified for most of the major forestry herbicides. but there is little information on the fate of these by-products in southern forest ecosystems. Hexazinone, imazapyr,

and sulfometuron methyl have been studied in the South, but glyphosate and triclopyr have not.

Soil composition is particularly important in determining herbicide persistence. Clay and organic matter adsorb herbicide molecules to varying degrees and this interaction results in advective dispersion and retarded movement for water soluble herbicides. Organic matter content is probably the most important soil characteristic affecting the coefficient of adsorption (K_D) (Shea 1989) and greatly affects microbial degradation through its influence on microbial population density (Gjerstad and Michael 1982).

Glyphosate has been extensively studied in agricultural systems. It is initially degraded to aminomethyl phosphonic acid, but ultimately to CO_2 with a half-life of from 3-130 days depending on the amount of organic matter in the soil (USDA 1984). Greater amounts of organic matter result in more rapid degradation of glyphosate, presumably because of the greater microbial population densities supported by the organic matter. The extensive data base on glyphosate has been reviewed (Grossbard and Atkinson 1984) and will not be covered in this paper.

Microbial degradation of hexazinone results in five major metabolites (USDA 1984), but only one of the metabolites retains any of hexazinone's ability to inhibit photosynthesis and that is at reduced levels (Sung et al 1982). Reports of the half-life of hexazinone in field soil studies range from less than three weeks to six months (USDA 1984).

The fate of imazapyr was studied in Piedmont and Upper Coastal Plain soils of Alabama following aerial application of 2.24 kg ae ha^{-1}. Imazapyr had a half-life of 19-34 days. It was detected below 30 cm in only 1% of the samples studied (Michael 1986). Movement below 30 cm was probably due to mass transfer in solution flow through large macropores (rotted out stump holes and root channels).

Sulfometuron methyl was studied on a clay loam soil in Mississippi and a sandy soil in Florida following application of 0.42 kg ai ha^{-1} by Michael and Neary (1987). Soil half-life ranged from 7-13 days and although slightly more mobile than imazapyr (Wehtje et al. 1987) sulfometuron methyl was not detected below 30 cm at either site. Sulfometuron methyl is rapidly hydrolyzed under acidic conditions to form saccharin and methyl-2-aminosulfonylbenzoate at a rate governed by soil pH and moisture (Anderson and Dulka 1985; Harvey et al. 1985). Other significant literature has been reviewed by Beyer et al. (1987) and will not be covered in this paper.

There is very little information on the fate of triclopyr, but the available literature has been reviewed (USDA 1984). Soil half-life is reported to be from 10-46 days in the field and from 79-156 days under aerobic laboratory conditions. Two metabolites are known which have half-lives of 8 to >300 days.

ENVIRONMENTAL IMPACT STATEMENTS AND RISK ASSESSMENT

In the past five years the USDA Forest Service has been involved in an intensive program to analyze the environmental impacts and, specifically, the human health risks of herbicide use on National Forest System lands. Regional environmental impact statements (EIS's) have been developed (or are in-progress) for all vegetation management methods as required by the National Environmental Policy Act of 1969 as amended (USDA-FS 1989a, 1989b, 1989c). These EIS's include risk assessments for herbicides because they are a focal point of public controversy and have raised questions of concern related to human health and safety, wildlife populations, and water quality. Site-specific Environmental Assessments can then be tiered to these regional EIS's or generic risk assessments to analyze the environmental effects of a vegetation management operation at a particular location.

A. EIS/Risk Assessment

A regional EIS is a broad analysis of all the known or foreseeable impacts of forest land management activities on the "total environment." Regional EIS's have been done on a physiographic unit basis (USDA-FS 1989a, 1989b, 1989c). The "total environment" includes human health and safety, wildlife, threatened and endangered plant and animal species, vegetation associations, soil, water, air, economic conditions, and social values. An EIS for vegetation management includes statements on the purpose, scope, and issues of the EIS, the management alternatives, the affected environment, the environmental consequences, public responses, and a record of decision.

A risk assessment is done within the context of an EIS or may be conducted separately for specific applications. It is much more narrow in scope as it concerns only the human health and safety aspects of herbicide use. A risk assessment consists of three steps: a hazard analysis, an exposure analysis, and risk analysis. The results of a risk assessment are used in determining the environmental consequences within an EIS and are used to guide the selection of a preferred forestry management alternative.

Risk assessments use a scientifically accepted methodology that compares herbicide doses that humans may get with doses likely to be safe to humans based on long-term studies on laboratory test animals. A conservative approach is employed in risk assessments that tends to exaggerate the estimated risks to human health. The conservatism inherent in this analytical methodology occurs in estimating herbicide exposure, in setting toxicity thresholds, and in extrapolating toxicity data. This exaggeration of the risks of herbicide application is done to ensure that a risk assessment errs on the side of protecting human health.

Three principal analytical components are used in a risk assessment to characterize potential adverse health effects of human exposure to existing or introduced hazards in the environment; hazard analysis, exposure analysis, and risk analysis (National Research Council, 1983). The hazard analysis requires gathering information that is used to determine the toxic properties of each herbicide. Literature searches, pesticide background

statements, and EPA registration support data are used to define the required toxicity levels: LD_{50}, systemic and reproductive no observed effect levels (NOEL's), carcinogenicity, and mutagenicity. Human hazard levels are derived primarily from the results of studies of animal models such as rats, mice, and rabbits. However, information on human poisonings, field studies of other organisms, and chemical structure are used to supplement laboratory data. The exposure analysis involves estimating single and multiple exposures of workers and the public. Scenarios are developed which identify the characteristics of exposed human populations and estimate single and lifetime doses. The risk analysis then combines the hazard analysis, the exposure scenarios, and the probabilities that the exposures could occur to predict the health effects on individuals. This last step includes comparison of herbicide-related risks to other common risks and to risks resulting from alternative vegetation control techniques. Conclusions derived from risk assessments are used to guide decision-making in EIS's or Environmental Assessments.

B. EIS/Risk Assessment Summaries

The conclusions from the risk assessments and EIS's for all the chemicals in all the physiographic regions and under all use scenarios are too complex to be adequately summarized here. The original documents should be read carefully to understand and appreciate the scope of the findings. Some general conclusions from several of the risk assessments are stated here for the herbicides hexazinone, glyphosate, imazapyr, sulfometuron methyl, and triclopyr.

In the Southern Region EIS's (USDA-FS 1989a, 1989b, and 1989c), the risk assessment concluded that acute oral and dermal toxicities were slight to very slight. For typical public exposure scenarios no member of the public, including sensitive individuals, should have any adverse systemic or reproductive effects due to any of the herbicides evaluated. For the maximum public exposure scenario used, higher risks could result due to exposures to triclopyr that occur from consumption of berries, but NOEL's are not exceeded. Risks to workers are higher because of greater exposure and the likelihood of higher doses, but for the herbicides specifically considered in this paper, margins of safety were still >100 under typical exposure scenarios. With the maximum exposure scenario, risks increase but exposures do not exceed NOEL's. For accident scenario exposures, risks to workers who did not wash off spilled herbicide were very high for glyphosate, hexazinone, sulfometuron, and triclopyr. Cancer risks for glyphosate were assessed because of some scientific uncertainty. Lifetime cancer risks were determined to be less than one in a million (equivalent to smoking 2 cigarettes). Glyphosate, imazapyr, and sulfometuron methyl are not mutagenic, and hexazinone and triclopyr have tested nonmutagenic in a majority of studies. None of the herbicides evaluated have been shown to bioaccumulate or act synergistically with other herbicides on humans.

The EIS's for the Southern Region concluded that other methods of vegetation control pose greater health risks to workers than herbicides. They also concluded that the herbicides evaluated met acceptable risk standards for terrestrial and aquatic wildlife when applied at typical rates using current methods. Care needs to be taken with herbicides concerning

threatened and endangered species. Herbicides do not adversely affect soil productivity and actually protect it by reducing compaction and erosion. Low application rates and mitigation techniques such as buffer strips result in only a very slight risk to water quality.

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CONCEPTION D'UNE AGROFORESTERIE EN MOYENNE MONTAGNE FRANCAISE

Jean-Luc GUITTON, chef de la division Techniques Forestières, groupement CEMAGREF de Clermont-Ferrand

François Xavier de MONTARD, chercheur à la station d'agronomie de l'INRA Clermont-Ferrand

FDC: 268: (234)

RESUME

L'agroforesterie, soit l'association sur un même terrain de l'arbre et de l'agriculture, n'est pas une nouveauté en Europe ; combattue par l'intensification et la mécanisation de l'agriculture, elle subsiste encore sous les formes du bocage et du paturage sous forêt claire.

Les besoins de diversification de l'agriculture, les progrès scientifiques et techniques permettent d'envisager hors forêt la production de bois de qualité à prix de vente élevé ; c'est un possible renouveau du sylvopastoralisme, dans ses deux formes rélictuelles et dans une nouvelle association, la plantation à faible densité d'arbres à bois précieux dans des prairies. Cet article en développe la conception, les difficultés et les recherches entreprises.

INTRODUCTION

Le terme d'agroforesterie peut se définir comme l'association délibérée et raisonnée de spéculations agricoles et d'arbres. Il inclut le sylvopastorisme qui désigne spécifiquement l'association culture d'arbres-élevage.

Cette association trés courante dans les siècles passés, détronée par l'agriculture spécialisée des dernières décennies, est de nouveau citée dans les discours actuels, particulièrement ceux traitant de systèmes extensifs. Nous présenterons donc dans la suite de cet exposé :

- l'intérêt des systèmes traditionnels et leurs limites,
- les raisons d'envisager un renouveau possible de l'agroforesterie,
- les difficultés rencontrées et les expérimentations prévues.

1/DES SYSTEMES AGROFORESTIERS TRADITIONNELS EN REGRESSION

Dans les pays occidentaux d'Europe cette association de l'arbre et de l'agriculture a été trés fréquente et se rencontre encore sous deux formes principales, le bocage et le pâturage sous forêt claire.

1.1/ Le Bocage

Le paysage rural d'enclos délimités par des haies ou des lignes d'arbres s'oppose à celui de la campagne ouverte où les champs forment un ensemble continu bien séparé des bois.

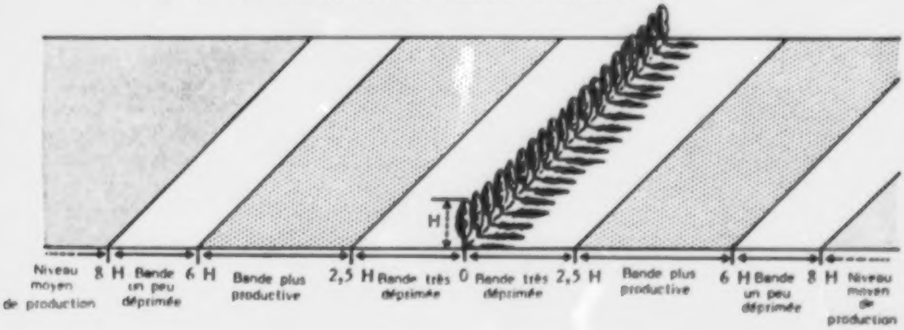
De nombreuses régions françaises (Normandie, Bretagne) et la plupart des régions de basse montagne, telle le Cantal, présentent ces types de paysages, aboutissant à une utilisation mixte de l'espace. Les haies entourent de tous côtés des pièces de terre en un réseau plus ou moins géométrique dont la maille est de taille variable. La végétation arbustive et arborée des haies varie selon les régions,sous forme de landes, buissons, taillis, arbres de haut jet.

L'arbre a de nombreux rôles, la protection par l'effet brise-vent, l'infiltration des eaux de ruissellement dans les nappes profondes, la clôture physique pour contenir les troupeaux, la production de bois et de divers menus produits, l'enrichissement de l'environnement, la production de feuilles pour l'affouragement.

L'effet brise-vent est maintenant, grâce aux études de l'INRA (Guyot, Seguin) bien connu.

On observe une disparité zonée des influences bioclimatiques (radiation, évaporation et vent) selon des bandes parallèles de part et d'autre des bordures principales, comme l'illustre le schéma suivant :

EFFET DE LA HAIE SUR LES TERRAINS VOISINS



- la bande placée au voisinage immédiat des arbres, couvrant une largeur de 1 - 2,5 H (H étant la hauteur moyenne de la haie) est affectée par la concurrence pour la lumière et l'eau et subit un net retard de croissance et de production ;

- la bande 2,5 - 6 H en permanence plus chaude est caractérisée par une plus grande précocité. L'augmentation de rendement allant de 15 à 20 % ;

- une bande située à 7 - 8 H est perturbée ; elle présente souvent des hétérogénéités de croissance et un rendement un peu déprimé.

L'augmentation de la production végétale globale sur l'ensemble de la surface protégée est généralement compensée par la perte de surface de la haie, mais la continentalité obtenue peut permettre la diversification de cultures, par exemple autoriser la production de primeurs ; elle a incontestablement des répercussions très positives sur le bétail qui pâture les prairies du bocage.

La Clôture physique par les haies, surtout quand elles sont implantées sur des talus est très efficace et durable. Cependant, de plus en plus fréquemment la haie mal entretenue et trouée doit être confortée par des lignes de fil de fer.

La haie forme une barrière à l'écoulement de l'eau dans les zones pentues, ce qui limite l'érosion et favorise l'infiltration profonde.

La production de bois de chauffage et de service par ces forêts linéaires est très importante dans des régions, comme la Manche, où le taux de couverture des bois et forêts est très faible, de l'ordre de 5 %. On peut considérer qu'en moyenne :

100 m de haie ont un accroissement moyen de 1 stère/an (soit l'équivalent de 140l de fioul)

100 m de haie bien conduite avec un arbre de haut jet tous les 10 m en moyenne fournit une valeur de bois d'oeuvre de 100 à 200 F/an.

A cela s'ajoutent les menus produits tels que les champignons, le gibier, les petits fruits qui se développent dans cet écosystème particulier.

Enfin dans de nombreuses régions où la ressource fourragère est limitée, les arbres émondés, tels le frêne, apportent un complément de fourrage en fin d'été.

La valeur environnementale est incontestable tant sur le plan humain que sur le plan écologique : la présence de coupures végétales entre des parcelles de terre tamponne le développement de maladies et de parasites.

1.2/ Le Pâturage sous forêt claire

Quelques pratiques subsistent encore :
- en Margeride sous pin sylvestre
- dans le mélèzin alpin
- dans les Landes sous pin maritime
- dans les régions méditerranéennes (déhesa espagnole)
- dans le maquis Corse.

Les points communs à ce sylvopastoralisme sont :

- l'obtention et le maintien d'une densité d'arbres forestiers peu élevée, voulue pour obtenir une croissance individuelle élevée, ou subie dans le cas de conditions de sol et de climat difficiles (résistance aux intempéries en montagne, faible pluviométrie) ;

- les caractéristiques de couvert des essences employées qui sont toutes à feuillage clair ;

- l'utilisation de races bovines, caprines ou ovines rustiques.

Dans ce système encore, l'arbre induit une diversification de la strate herbacée delon le degré d'ombrage et un étalement de l'épiaison des graminées dans le temps, favorable à une meilleure valorisation en élevage extensif.

Ces systèmes, bocage ou forêt claire, ont tous, malgré leurs avantages écologiques et les efforts de vulgarisation et de financement (haies brise-vent) considérablement régressé du fait de la modernisation et de la spécialisation de l'agriculture, en vertu des lois suivantes :

- la mécanisation oblige à travailler des grandes parcelles,
- l'exode rural raréfie la main d'oeuvre pour l'entretien des haies,
- la baisse du prix du bois d'oeuvre ou de chauffage diminue l'attrait économique de la haie,
- la spécialisation de l'agriculture et de l'élevage réduit l'emploi des races rustiques,
- le savoir faire dans l'entretien, le renouvellement des haies ou des forêts claires a disparu.

2/ UN RENOUVEAU POSSIBLE DE L'AGROFORESTERIE

De même que certaines techniques deviennent un moment dépassées puis renaissent sous d'autres formes du fait de changements sociologiques et d'innovations, à l'heure actuelle, sous nos climats tempérés, certaines formes d'agroforesterie peuvent à nouveau être développées. Les facteurs déterminants sont d'ordre socio-économiques et techniques.

2.1/Des raisons socio-économiques liées à la remise en cause de la PAC

La profonde réorganisation de l'agriculture européenne dans les années à venir doit prendre en compte :

- le blocage à un niveau stable de la production des biens alimentaires, du fait d'une consommation stagnante, en opposition avec une productivité toujours croissante (+ 2 % l'an) ;

- des problèmes d'environnement et de pollution du milieu naturel (par l'air et par l'eau) dans les régions les plus productives ; la reconstitution de coupures boisées dans les régions de champs ouverts peut limiter l'érosion éolienne, pluviale, le transport à distance d'engrais, de pesticides ;

- une certaine volonté politique, de ne pas créer de nouveaux déserts humains par des reboisements trop systématiques dans les zones en déprise. La recherche et le développement de techniques extensives doivent permettre le maintien d'éleveurs et l'ouverture du paysage.

- la faim de bois de la CEE : 70 millions de m3 équivalent bois rond sont importés annuellement et le poste "bois" est la seconde source de déficit pour la communauté aprés l'énergie. L'importation de feuillus exotiques sera de plus en plus difficile à mesure que les forêts tropicales s'amenuisent et que l'utilisation se développe sur place. Une production de bois feuillus ou résineux de qualité trouvera toujours preneur à des prix se revalorisant dans l'avenir.

2.2/ Des raisons techniques

Dans l'optique de plantations d'arbres à bois précieux à grands espacements en prairie, **plusieurs progrès techniques sont apparus ces dernières années** :

- le **niveau de sélection génétique** toujours croissant permettra de disposer bientôt de clones (issus du bouturage d'arbres supérieurs) sûrs tant pour leur rythme de croissance que pour la qualité du fût. Ce stade clonal est d'ores et déjà atteint pour le merisier ;

- **les tubes-abris**, manchons en matière plastique de section variable, long de 60 cm à 225 cm, développés au départ pour protéger les plants contre la dent du gibier doivent les soustraire efficacement de l'appétit du bétail ovin ou bovin ;

- **la connaissance de l'élagage et des tailles** de formation pour les feuillus précieux et le développement d'outils performants (scies à chaînes, meuleuses, sécateurs pneumatiques) permettent d'obtenir, d'un arbre isolé, un fût droit, sain, élagué de 6 m de hauteur.

-**la connaissance des besoins d'éclairement** d'une flore herbacée productive et les études du comportement du bétail dans les conditions de plein vent.

- le **maintien d'une flore herbacée productive** grâce à une faible densité de plantation ou une éclaircie en fin de révolution. Ce modèle régulier peut être modifié profondément par regroupement des arbres en bouquets ou par alignement, donnant tous les intermédiaires entre la sylviculture classique et l'arboriculture à bois précieux.

2.3/ La relance de l'agroforesterie

Les mutations socio-économiques actuelles ainsi que les progrès techniques autorisent donc à envisager une relance de l'agroforesterie, sur la base de production de bois d'oeuvre de qualité à prix de vente élevé, sous les deux formes classiques déjà décrites, le bocage et le paturage sous forêt, et sous une forme nouvelle, la plantation en prairie.

- la modernisation du bocage traditionnel

La conception d'une haie brise-vent comportant plusieurs étages de végétation, une state basse arbustive, des arbres de taille moyenne et des tiges de haut jet est maintenant bien connue et vulgarisée dans des ouvrages tels que celui de l'IDF(la réalisation pratique des haies brise-vent et bandes boisées).
La pratique de rajeunissement et de complémentation de haies existantes par contre n'est pas encore développée, mais peut s'envisager sur les bases techniques de la plantation en prairie énoncées ci-après.

- l'utilisation d'herbivores au pâturage sous forêt,

Dans certaines régions à forte compétition pour le foncier, la valorisation des premières éclaircies éclaircies est difficile et se traduit par des retards dangereux pour la stabilité du peuplement ; l'introduction du pâturage sous forêt, alors que les arbres ne craignent plus l'écorçage peut permettre ces travaux et conduire à une sylviculture dynamique de production de bois élagué.

2.4/ des plantations à faible densité en prairie

L'association de la production de bois d'oeuvre de qualité et de l'élevage est riche :

- l'arbre a un rôle de production de bois de qualité : avec des feuillus précieux, on peut prétendre obtenir en 40/50 ans des grumes au prix de vente au m3 supérieur à 1000 F ; des résineux élagués pour le placage peuvent également être trés valorisant en 30/40 ans.

- l'arbre a un rôle de protection du bétail et de diversification des dates de maturation de l'herbe, il limite la production de la strate inférieure et en facilite la maitrise par le pâturage.

- inversement le maintien du bétail et de l'élevage permet le contrôle de la végétation concurrente, une fertilisation favorable à l'arbre et l'environnement humain nécessaire pour les soins de taille et d'élagage en vue de l'obtention d'une grume droite, saine et sans noeuds.

PLANTATION D'ARBRES FORESTIERS EN PRAIRIE

2 à 3 ans après plantation

15 à 20 ans après plantation

Le modèle de base testé consiste en :

- la plantation d'une centaine de tiges à l'hectare (espacements de 8 x 12 m) de feuillus précieux, érables, frênes, merisiers, noyers, voire de résineux comme le mélèze dans une prairie pâturée;

- la protection des jeunes arbres par des tubes-abris de 1,80 m ou 2,25 m de hauteur selon qu'il s'agit d'ovins ou de bovins. Un traitement herbicide localisé autour du plant facilite grandement le démarrage de l'arbre.

- la conduite de l'arbre par élagage au fur et à mesure qu'il grandit. L'arbre sera élagué et taillé pour obtenir un tronc droit sans noeud d'une hauteur franche d'au moins six mètres de hauteur.

- le maintien d'une flore herbacée productive grâce à une faible densité de plantation ou une éclaircie quand les produits obtenus en valent la peine.

- les régions de moyenne montagne présentent des conditions très favorables, des précipitations élevées induisant une croissance rapide des arbres, une majorité de terres agricoles exploitées en prairie.

3/ DES OBSTACLES A SURMONTER PAR L'ETUDE ET L'EXPERIMENTATION

3.1/ Plusieurs incertitudes et difficultés demeurent

- le choix des espèces forestières et la mise au point des techniques de plantation. Une région comme l'Auvergne, présente différents étages altitudinaux depuis la plaine jusqu'à la montagne, des sols de richesse chimique et de profondeur variable.

Les arbres forestiers sont très sensibles à la concurrence de l'herbe les premières années : comment limiter cette concurrence au départ de la plantation ?

- <u>Le contrôle de la compétition entre production herbacée et productions arborée.</u>

Les études en forêts pâturée claire, ont montré que le niveau de couvert maximal admissible pour la strate herbacée se situait aux alentours de 60-70 %.
Il faut vérifier que ce seuil ne varie pas avec la nature du feuillage, avec la hauteur élaguée, la disposition des arbres.
La concurrence entre les deux productions se fait également par la litière qui peut modifier le cycle biologique des éléments nutritifs.

- <u>La protection des arbres contre le bétail</u> : les ovins comme les bovins dégradent les arbres de trois manières
* ils mangent les feuillages et les jeunes pousses et en arrachent souvent les rameaux
* ils écorcent les arbres
* ils se frottent contre les troncs et risquent de briser les jeunes arbres.

En attendant de trouver des moyens répulsifs efficaces et durables, il faut donc isoler l'arbre. Le manchon plastique solidement tuteuré, malgré les contraintes qu'il présente et son coût constitue une bonne réponse; il s'y produit aussi un effet-serre qui hâte la croissance des premières années. Cependant le manchon se dégrade sous l'influence des rayons ultra-violets : il ne doit pas durer plus de 5 à 7 ans et il faudra sûrement envisager la protection du tronc contre les morsures et le frottement pour les essences les plus sensibles (merisier).

- <u>Les obstacles sociologiques, économiques et juridiques.</u> Lorsque la technique sera au point, il sera nécessaire de lever ces obstacles. Ils ne doivent pas être mésestimés :
- instituer des possibilités de financements extérieurs à l'agriculture,
- dépasser le clivage ancestral forêt-agriculture,
- permettre les ententes propriétaires-locataires pour l'entretien et le bénéfice des arbres et prévenir les conflits entre eux.
- permettre ces types de plantation dans le cadre de la réglementation des boisements.

3.2/ Trois grands types d'expérimentations

Pour tenter de répondre d'ici cinq ans aux questions précédemment posées, un programme d'expérimentation et d'études est conduit en région Auvergne par la Division Techniques Forestières du groupement CEMAGREF de Clermont-Ferrand en liaison avec la station d'agronomie de l'INRA de Clermont-Ferrand et les lycées agricoles.

Trois grands types d'expérimentations ont été développpés :

- des plantations d'arbres forestiers en prairie dans les conditions d'élevage courant pour affirmer le choix des essences forestières, les moyens de protection des arbres, les méthodes culturales à la plantation, étudier le comportement des animaux, dégager des coûts d'instatllation ;

DISPOSITIF EXPERIMENTAL DE BASE DES PLANTATIONS EN PRAIRIE

Essai de densité avec une essence de base

Densité Forestière	200 tiges par ha	100 tiges par ha	50 tiges par ha	Pâturage seul

Essai de comparaison d'autres essences

E1 100 tiges par ha	E2	E3

·Placette élémentaire de 50 à 100 ares

- l'observation de peuplements feuillus adultes existants pour vérifier les seuils d'éclairement réels, le fonctionnement du cycle de l'azote et de l'eau et déterminer la sylviculture optimale ;

- l'ouverture du pâturage de jeunes plantations défensables d'épicéas, de douglas et de pins sylvestres pour étudier la vitesse de reconstitution d'une strate herbacée appétente.

Parrallèlement sera menée l'étude des conditions sociologiques juridiques et financières nécessaire au développement de l'agroforesterie en collaboration avec d'autres centres de recherche français et étrangers.

CONCLUSION

L'agroforesterie tempérée a donc périclité devant le développement de l'agriculture industrielle des "dernières trente glorieuses". La mise en cause de cette agriculture rend nécessaire la relance de cette association des arbres et de l'agriculture d'autant que les progrés de la génétique, des innovations telles que le tube-abri, les besoins de la CEE en bois y sont favorables.

Cependant, l'agroforesterie tempérée associant des plantations à fort espacement de feuillus précieux à l'élevage n'est en Europe qu'à l'heure des toutes premières expérimentations pour préciser les essences forestières à utiliser, les techniques, la sylviculture et la gestion des troupeaux.

Les réflexions, études et expérimentations menées à la division Techniques Forestières du groupement CEMAGREF de Clermont-Ferrand en liaison notamment avec les agronomes de l'INRA progressent pour que l'agroforesterie tempérée dépasse le stade du rêve utopique d'une société qui se veut plus écologique et devienne dans quelques années un modèle d'organisation de l'espace offrant au monde rural des perspectives nouvelles de développement.

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STATUS OF AGROFORESTRY RESEARCH IN SOUTH ASIA

P K Khosla[1] and Parvinder Kaushal[2]

1 Director Extension Education, Dr Y S Parmar University of Horticulture and Forestry, Solan, HP, India

2 Assistant Professor, Department of Forestry, Punjab Agricultural University, Ludhiana, Pb, India

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SUMMARY

South Asia, embodying Afghanistan, Pakistan, India, Nepal, Bhutan, Bangladesh and Sri Lanka is known for its diverse climate, soil, topography, vegetation and farming systems. The region is thickly populated with poor economy and disturbed ecology. The excessive biotic pressure has resulted in the development of different agroforestry systems ranging from simple forms of subsistence terraced agriculture with multiple trees to `taungya' and shifting cultivation and complex multistoreyed homestead gardens. Status of agroforestry research is discussed.

Keywords: Agroforestry, South Asia, Afghanistan, Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka

INTRODUCTION

South Asia for all practical purposes is synonymous with the Indian sub-continent, where agriculture and animal husbandry have co-existed for the sustenance of its economy through the ages. The rich agrarian heritage lured the settlement of invaders from the West resulting in thick population density then and now. The topography of South Asia is diverse, varying from hostile deserts to fertile plains, coastal regions and valleys to high hills and inaccessible inner Himalayan ranges. South Asian region is the only global part which encounters both cold and hot deserts. Its land provides a rich depository of gene pool representing almost the entire flora of the world - tropical to alpine.

The biotic pressure (human & cattle) may be accounted as the prime single factor for the poor economy and disturbed

ecology of the area. On account of age old dependence for fodder, fuel, fibre, etc, on natural resources, a wide diversity of farming systems has emerged from subsistence agriculture to shifting cultivation and complex homestead gardens. These are either the relics of the natural vegetation or have been evolved to the level of well developed cropping systems.

The evolution of the farming systems emerged locally varying from horti-silvi-pastoral in Afghanistan; silvi-pastoral in the deserts and hilly regions of India, Pakistan, Nepal and Bhutan; monocropping without arboreal component in the Indus basin; shifting cultivation in Bhutan, Nepal and Eastern India and homestead multistoreyed systems in Bangladesh, South India and Sri Lanka. The developmental activities in agroforestry have become quite fast in the region on account of linkages with social forestry and community forestry projects. The fragile Himalayan ecosystem is attracting various international donors and all conservation projects include the agroforestry research component on plantation of MPTs and NFTs. The status of agroforestry research in South Asian countries is summarized along with the basic data on land use systems, population (human & cattle), climate, topography, etc., (Anonymous, 1973;1989-90).

A f g h a n i s t a n

Geographic location/area: 36°15'-37°15'N; 71°30'-75°E; close to Central Asia; 647,500 km^2. Population: 15 m. Topography: mountainous terrain of steep ridges and deeply incised valleys; plains rare. 20% area (below 1000 m) a desert; 10.5% above 3000 m unsuitable for human activity. Climate: dry arid in plains to cold desert in high ranges. Rainfall varies from 500-1000 mm; above 2000 m mostly in the form of snow. GNP per capita: US$250. Landuse pattern: 14 m ha under agriculture; 53 m ha irrigated along river banks and wells and underground channels. Arable land and fruit trees 12%; meadows, pastures and rough grazing lands 5%; wood and forests 2%; non-agricultural land 81%. Land holdings small, average size 1.7 ha. Livestock population: 27 m; cattle breeding a profession. Agricultural crops: maize, millet, wheat, rice, cotton, sugarbeet, potato, citrus, temperate fruits (pome, stone, nut), castor oil, asafoetida, spices, etc. Food self-sufficiency : high value cash crop sustain the economy. Prevalent agroforestry systems: poplars and willows are planted along water channels and river banks. *Quercus balut* at low altitudes used for fire wood; in higher hills silvi-pastoral systems exist with dense coniferous forests. Wild trees of chilgoza sustain economy in dry temperate zone. Major constraints: irrigation ; limited arable land for agriculture; degradation of temperate watersheds; cattle mainly nomadic; pastures unproductive. International support: USA (Hemland valley); USSR (Jalaland valley); FRG in the Province of Paktya; UNDP/FAO; Czechoslovakia. Choice of species: *Populus*, *Salix*,

Ailanthus, Robinia, etc. Status of agroforestry research: wherever possible the planting of the poplars - quick growing tree-is fostered, but it is unlikely that Afghanistan will be able to meet its national requirement from its own resources. Evolution of different clones of poplars is made through the UNDP funded project. Suggestions: large cattle population warrants the development of silvi-pastoral systems. Poplar and willow can also provide leaf fodder. Agri-horti-silvicultural systems should form the basis of integrated land management policy. Grafting of economic species on wild growth is recommended for optimising and exploiting the wild flora. Seed orchards of chilgoza and other nuts should be raised.

B a n g l a d e s h

Geographic location/area: 88°5'-92°50'E; 26°50'-26°40'N; along Bay of Bengal on the southeastern border of India; 143,999 km². Population: 104 m. Topography: hills in the eastern region; coastal delta; tropical mainland. Climate: tropical monsoon; extreme humidity, heavy rainfall from June-Sept; rainfall 1250 mm (West) and 5000 mm (northeast). GNP per capita: US$140. Landuse pattern: arable land 8-9 m ha. Livestock population: 40 m; livestock rearing not a means of livelihood. Agricultural crops: cropping pattern follows rainfall; rice farming in 80% of the cropped area; jute another cash crop; wheat, sugarcane, cotton, potato and oil seeds are also cultivated. Tea farming confined to hills. Prevalent agroforestry systems: shifting cultivation as practised in hill slopes being replaced by sedentary agri-silvi-horticultural systems. Homesteads as built on mounds are common, provide fuel, food, fodder and other material. Homesteads range from 0.20 to 1.414 ha (Leuschner and Khaleque, 1987). Interfacing of Acacia nilotica in rice fields is common (Abedin et al, 1987; FAO, 1987). NFTs planted in tea gardens in hills. Major constraints: floods; low yield from rice farming; small sized farms and homesteads; shifting cultivation; degradation of mangrove and hill forests. Food self-sufficiency : a food deficit country; productivity of rice is lowest; jute cultivation decreasing. International support: Ford Foundation; USAID; IDRC; FAO/UNDP; Winrock. Status of agroforestry research: homestead agroforestry practised by almost every rural dweller excepting landlords practising extensive rice and jute farming. No systematic data has been generated on agroforestry. Specific crop and cropping patterns are associated with trees, locations and land types. The research on agroforestry is at the level of diagnosis and evaluation stage. Emphasis on agroforestry is also highlighted such as Community Forestry Programme; Khas and Protected Forests; Chittagong Development Project; Hill Tracts Development Project and Jhumia Rehabilitation Project, Bandarban (ICIMOD, 1986). Research on agroforestry (homestead) is conducted by

Bangladesh Agriculture Research Institute (BARI), Winrock, University of Dhaka and Bangladesh Forest Institute along with the support of Ford Foudation (Chun Lai, 1989). Choice of species: *Dendrocalamus*, *Artocarpus*, *Trewia*, *Terminalia*, *Acer*, *Quercus*, *Castanopsis*, *Alnus*, *Melia*, *Toona*, *Morus*, *Borassus*, *Bombax*, etc. Suggestions: efficient homestead models of multi-tiered cropping system need to be worked out. International donors should help to create a central agency for coordinating agroforestry research. Better genetic stock can help to improve the productivity. Specific agroforestry models should be worked out as per cropping systems in hills, coastal area, and on mainland.

B h u t a n

Geographic location/area: 88°45'-92°15'E; 26°30'-28°30'N; Eastern Himalaya; 47,000 km^2. Population: 14 m. Topography: mountainous; low hills to alpine; highlands in the inner Himalaya. Climate: altitudinal effect on climate; North cold with snow on summits, Centre (1000 mm) moderate and South humid sub-tropical (2000 mm). GNP per capita: US$160. Landuse pattern: forests 35.4%; grazing and non-agricultural lands 63.8%; arable land 0.74%; agriculture 8.8%. Livestock population: 0.55 m. Agricultural crops: maize, barley, buckwheat, millet; citrus in low hills and apple in uphills. Prevalent agroforestry systems: silvi-pastoral; shifting cultivation. Major constraints: fodder shortage; excessive denudation; soil erosion; watershed deterioration; low productive terraced agriculture; shifting cultivation. (Thinley, 1988). Food self-sufficiency : subsistence farming; poor agricultural practices; marginally self-sufficient. International support: FAO/UNDP; Asian Development Bank; India. Status of agroforestry research: agroforestry is linked with upland conservation by planting multipurpose trees. Choice of species: *Acer*, *Ailanthus*, *Albizia*, *Artocarpus*, *Bauhinia*, *Exbucklandia*, *Betula*, *Carpinus*, *Castanopsis*, *Toona*, *Ficus*, *Butea*, *Grewia*, *Quercus*, *Morus*, *Terminalia*, etc. Suggestions: horticultural trees (citrus in low hills and stone fruits and apple in mid and high hills) should also be incorporated in the farming systems for easy flow of cash. The country may join the network of the All India Coordinated Research Project on Agroforestry of the ICAR. Silvi-pastoral models should be developed on priority to meet fodder deficiency.

I n d i a

Geographic location/area: 68°7'- 97°25'E; 8°4'-37°6'N; 3,166,829 km^2. Population; 840 m. Topography: Himalaya on the North, desert in the West, tropical to sub-tropical region in

the East, plateau in the Centre and South; Western and Eastern Ghats along the coast. Climate: tropical, semi-arid, arid, sub-tropical temperate and alpine; rainfall from less than 100 mm in Western Rajasthan and cold desert areas of Lahaul, Spiti and Ladakh to above 12000 mm (Cherapunji); temperature rises above 49°C in the sandy desert and falls below 0°C in hills. GNP per capita: US$270. Landuse pattern: agriculture - 46.4%; forests 22.8%; other uncultivated land 12.9%, non-agricultural uses 4.9%, barren and unculturable land 13%. Livestock population: 400 m. Agricultural crops: a wide range of cereals, oil seeds, vegetables, fruits, fibre yielding plants, sugarcane, fodder, medicinal plants, etc. Wheat and rice major crops; maize cultivation extends to rainfed areas. Prevalent agroforestry systems: rich in tree crop combinations from trees on the fallow lands in the Indo-Gangetic plains, 'taungya' and shifting cultivation in the East; silvi-pastoral systems in the desert and hills; horti-silvi and horti-agricultural in plains and mountains and complex multi-storeyed systems in the South. Major constraints: fuel shortage;use of cowdung for fuel; fodder availability only 40% of the need; heavy biotic pressure (both human and cattle); unproductive cattle; excessive denudation; floods; drying of water sources, etc. About 175 m ha area is ecologically degraded (Bhumbla & Khare, 1984). Food self-sufficiency : green revolution in the sixties is still affected by seasonal vagaries. International support: World Bank, FAO, UNDP, IDRC, Ford Foundation, USAID, ODA, SIDA, CIDA, ADB, etc. Status of agroforestry research: organiztion of first agroforestry workshop in 1979 at Imphal led to the development of the All India Coordinated Research Project of the ICAR on Agroforestry in 31 Regional Centres. The researches are monitored on survey, diagnosis and design of the existing agroforestry systems, selection of MPTs and their evaluation and intercropping of trees and crop management studies. A National Centre on Agroforestry started at Jhansi in 1989. A Centre on Advance Studies on Agroforestry for imparting postgraduate education was started in 1987 jointly by the Parmar University, Solan (HP) and CS&WR&TI, Dehra Dun (Chinnamani, 1990). In the Himalayan region MPTs' like *Grewia optiva*, *Ulmus wallichiana*, *Ailanthus excelsa*, *Trewia nudiflora*, etc., have been identified. In the mid and high hills studies have been initiated on integration of fruit trees with high value cash crops like medicinal plants, turmeric, potato, tomato, pea, cauliflower, etc. Improvement of pasture and other silvi-pastoral models are being assessed. The diagnosis of Indo-Gangetic plains displays intensive agrarian activity without woody components in the West while in the East it incorporates a larger amount of perennial vegetation. Eucalypts, poplars and leucaena have been shown to be economical with wheat and rice. The emphasis is on the plantation of wild fruits like *Amla*, *bill*, *Jaman*, *ber*, *mulberry* along with teak, *sissoo*, *khair*, *babul*, *neem*, *siris*, etc. Apiculture and pisciculture have become popular. Tree crop interaction studies of different combinations have shown higher or equivalent yields. In humid and semi-humid regions shifting

cultivation, 'taungya' and homestead agroforestry systems are seen along with livestock poultry and fish. In the eastern coastal regions *Dalbergia sissoo* and guava combinations give high paddy and wheat returns. In the degraded sites soybean gives higher yield with different tree combinations. Arid and semi arid regions have been integrating *Prosopis cineraria* through the ages with farming systems. A diagnostic survey for the region has been completed and experimental trials with trees and crops including vegetables and grasses are being evaluated. Intercropping of grasses with *Acacia tortilis*, *Albizia lebbeck* and *Holoptelea integrifolia* have been shown to yield higher productivity (Shankarnarayan et al, 1987). Research on agroforestry in tropical South India ranges from alley cropping to agri-silviculture, silvi-pastoral and homestead combinations. Hedge-row of *Gliricidia* with hybrid napier has given higher biomass. *Casuarina equisetifolia* with hybrid napier yielded 23.4 t $ha^{-1}yr^{-1}$. The current status of research on agroforestry has been reviewed by Kaushal & Chinnamani (1989) and Chinnamani (1990). Suggestions: Considering the wide diversity of agroforestry systems, regrouping of research in four physiographic regions would be the right step. A large amount of data is being generated on nutrient budgeting and biomass evaluation, yet very little information exists on genetic improvement of multipurpose trees. Efforts should also be made to exploit the wild woody resources by grafting these with species/strain of economic value. Agroforestry curricula should appear in school and college text books. Strong extension services are required for speedy transfer of technology.

N e p a l

Geographic location/area: 80°15'-88°15'E; 26°20'-30°10'N; southern slopes of the Himalaya; 147,141 km^2. Population: 17 m. Topography: rectangular in shape with low, flat fertile land adjacent to India, Shiwaliks, mid hills and inner Himalayan ranges upto 3000 m and Great Himalayan mountains up to 6100 m. Climate: sub-tropical to alpine. GNP per capita: US$160. Landuse pattern: arable land 12%; forests 33%; meadows 15%; rest non-agricultural land; subsistence agriculture with 18 major cropping systems; annual deforestation 2% (ADB/HMG:N,1982); animal husbandry vital component of farming. Livestrock population: 16 m. Agricultural crops: paddy 60% (upto 2000 m); maize 24% (upto 2500 and occasionlly 3000 m); other crops - wheat, potato, sugarcane, gram, pulses, millet, vegetables, rape seed, barley, buckwheat. Prevalent agroforestry systems: degraded silvi-pastoral; terraced agri-silvicultural system sporadic throughout the country; isolated trees check soil erosion on steep terraces (Fonzen & Oberholzer, 1984); occasional strip/block plantations of multipurpose trees. Major constraints: dry farming on unproductive terraces; excessive deforestation and denudation of catchments; fodder and

fuel shortage (existing forests will disappear in 14 years in upper hills and 25 years in low hills (ADB/HMG:N, 1982); high livestock population; excessive fires; poor regeneration of natural forests (Griffin et al, 1988). Food self-sufficiency : although marginally a food surplus country but insecurity during drought. International support: FAO, World Bank, SIDA, CIDA, ODA, IDRC, Ford Foundation, ADB are involved in the developmental projects with forestry as an integral part such as Integrated Hill Development Project (SATA) for Central Nepal; Nepal - Australia Forestry Project (NAFP); Hill Area Rural Development Project (ODA). Status of agroforestry research: inspite of the technological packages that are tested and evaluated in Nepal for conservation and biomass acceleration through global expertise the researches on agroforestry lack a strong base. Royal Forest Department, Forestry Faculty of Tribhuwan University and ICIMOD are the recognised research organisations. Agroforestry is mainly in the form of community forestry with a few success stories. Cultivation of maize with nitrogen fixing trees can produce 50% more yield along with 2 t ha^{-1} of fuelwood. Suggestions: the country should consolidate existing international support for agroforestry development. There is a strong need to create a separate organisation so that along with hill rehabilitation, there is biomass production acceleration leading to economic amelioration of the people. In valleys along irrigated sources horticulture (sub-tropical and temperate fruits) should form an integral part of farming. Emphasis should be given to plantation of wild fruits in community forestry. Sufficient genetic stock is available in institutes situated in plains neighbouring Nepal and other hill states of India.

P a k i s t a n

Geographic location/area: 60°55'-75°30'E; 23°45'-36°50'N; South-West Asia.796,095km^2. Population:102m. Topography:arid and semi arid with two-third under mountains and desert; altitude from sea level to 6000 m. Climate: weak tropical, arid conditions in North and West; sub-tropical to alpine in hills. GNP per capita: US$350. Landuse pattern: forests 5.2%; cultivable waste 12.8%; not available for cultivation 26.4%; agriculture 23.3% (13.4 m ha irrigated by canals). Livestock population: 96 m. Agricultural crops: cotton, rice, millets, maize, sugarcane, barley, oil seeds, etc. Tropical vegetables, fruits; in hills temperate fruits and nuts. Prevalent agroforestry systems: agri-silviculture (rare); irrigated and unirrigated block plantations of multipurpose trees; silvi-pastoral systems in mountains and desert. Major constraints: fuelwood shortage in the entire country; high density of cattle population; fodder deficiency in desert and hills; degradation of catchment areas; developed farming system refrains from mixing of trees with crops. Food self-sufficiency : agrarian activity at peak due to canal irrigation in the upper Indus

basin. International support: World Food Programme (Turbela - Mangla Watershed Management Project); West Germany (Kaghan Forest Intensive Project); Netherland (Malakand Social Forestry Project); USAID (F/FRED Project); FAO/UNDP (Integrated Rural Development Project). Status of agroforestry research: agroforestry is not popular even in the desert and mountainous regions, with subsistence agriculture the concept of integrated landuse system has not percolated at the grassroot level. Agroforestry is seen only through the umbrella of social forestry pursuits. People's participation in upland conservation is sought by providing fuel and fodder through watershed management projects. Pakistan Forest Research Institute, Peshawar is actively engaged in collecting experimental data on tree crop interface (Sheikh, 1987). Sheikh et al, (1985) reported that in irrigated plantations poplar did not suppress the grain/straw yield of wheat whereas in sugarcane the yield was slightly less (70 t ha^{-1}) than the monoculture (80 t ha^{-1}). Sheikh (1988) also reported that most trees induced the yield within 8 to 10 m distance from the base of the tree. Choice of species: *Acacia nilotica*, *Dalbergia sissoo*, *Eucalyptus* spp, *Melia azedarach*, *Albizia* spp., *Populus deltoides* clones (*P. ciliata* in hills), *Azadirachta indica*, *Bombax ceiba*, etc. Suggestions: fuelwood is a major constraint and efforts are being made to meet it through block plantations of poplars, eucalypts and other MPTs. Since these plantations are raised with a commercial approach, an ensured market needs to be developed otherwise the common slump of poplar wood from US$20 to US$6 (dia 20 cm) per tree is likely to affect the raising of these plantations on private lands (Sheikh, 1988). For marginal farmers multistoreyed agroforestry systems involving crops + fruits + forest trees needs to be diagnosed and designed as per area requirement. In hills a combination of fruit and vegetable culture should be encouraged. For desert areas silvi-pastoral models are required. There is need for central agency for undertaking agroforestry research.

S r i L a n k a

Geographic location/area: 79°41'-81°54'E; 5°55'-9°51'N; near southern Indian peninsula; 65,610 km^2. Population: 17 m. Topography: diverse physical landscape with wide coastal area, highlands and undulating low hills. Climate: tropical; four major rainfall zones; wet zone (2500 mm), intermediate zone (1875-2500 mm), dry zone (1250-1875 mm) and arid zone (less than 1200mm). GNP per capita: US$400. Landuse pattern: influenced by climate; arable 8.5%; plantations 11.9%; gardens 8.8%; shifting cultivation (*chena*) 15.1%; meadows and permanent grasslands (6.4%); wood and forests (44.2%), non-agricultural land (5.1%). Livestock population: 4 m; pastures limited. Agricultural crops: tea, rubber and coconut dominate the economy. Paddy another cash crop - mainly for subsistence and

not undergone diversification. Other plantation crops - cocoa, coffee, tropical vegetables and fruits; clubs, nutmeg, etc. Prevalent agroforestry systems: embodies diversified agroforestry systems as classified for South Asia (Nair, 1983); multistoreyed homesteads called Kandayan gardens yielding fuel, fodder, food, timber, medicine and as well providing habitation for wild life (Jacob and Alles, 1987). Intercropping of cocoa and coffee along with rubber, coconut and tea is becoming popular (Newman, 1985); interculture of nitrogen fixing trees in tea gardens is a common practice (Beer, 1987). Major constraints: excessive land clearance for plantation crops; shifting cultivation; fodder deficiency. Food self-sufficiency : self sufficient, returns from homesteads make it a economically rich country of South Asia. International support: FAO/USAID; UNDP; F/FRED, ADB. Status of agroforestry research: The Minor Export Crops Department, Matale is studying the possibilities of intercropping coffee, cloves, nutmeg and pepper along with coconut, tea and rubber plantations. Cultivation of pastures/fodder is also studied. In addition pineapple, banana, yams, sweet potato, pepper and rice are also intercultured (Nanayakkara, 1987). No efforts have been made to study the yield of Kandayan gardens. *Albizia*, *Gliricidia*, and *Leucaena* in coconut plantations for ten years provided biomass along with support to pepper plant. Choice of species: *Dendrocalamus* *Terminalia*, *Bombax*, *Leucaena*, *Gliricidia*, *Albizia*, *Eucalyptus*, *Acacia*, etc. Suggestions: Kandayan gardens system of agroforestry can become more productive with improved management techniques and better genetic stock. For fodder shortage silvi-pastoral system need to be worked out. The country needs a bigger central agency for carrying out agroforestry research.

CONCLUSIONS

- The existing diversity in agroforestry ranges from monoculture without trees to the homesteads which are ecological relics of the natural ecosystem. Shifting cultivation falls midway and should be substituted by improved homestead models.

- Silvi-pastoraal systems will continue to play an important role in the desert, and degraded lands. The rehabilitation of these areas should have priority over biomass production.

- There is need to demonstrate usefulness of interfacing trees in the mechanised farming while for other systems it is desired to improve the genetic stock of various woody components for higher productivity. Where horticulture is sustaining the economy (cash flow), the need is to develop suitable high yielding fruit + tree + crop combinations.

- The benefits of some man-made agroforestry systems involving

plantation crops like tea, cofee, rubber, cocoa, coconut with NFTs have gone to rich farmers on account of heavy investment and absence of cooperative systems.

- Scarce cultivable land brings a clash between food and fodder production. Fodder and fuel is mostly obtained from natural resources.

- The poor quality of genetic stock of both animals and plants yields low productivity (excepting Indus basin).

- Agroforestry research in South Asia is at the diagnostic and evaluation stage. In hills, trials on a variety of tree-crop combinations are required to be conducted. The success stories of interculture need to be replicated over large areas.

- On the analogy of All India coordinated Project on agroforestry in India, a broad based project can be developed within the SAARC countries.

- To motivate the rural masses the combination of agroforestry should appear in school, college and university curricula including agriculture and forestry education.

- Training programmes should be conducted for the benefits of the farmers.

- India is capable of providing technical know-how on research, training and extension in agroforestry. This capability should be utilized to the maximum.

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SILVOPASTORAL SYSTEMS WITH RADIATA PINE IN SOUTHERN TEMPERATE ZONES

R.L. Knowles[1], R.W. Moore[2], and B.R.N. Leslie[3]

[1]Forest Research Institute
Rotorua, NEW ZEALAND

[2]Department of Conservation and Land Management
Busselton. WESTERN AUSTRALIA

[3]Arauco Forestal
Chillan, CHILE

FDC: 268: 174.7 Pinus radiata D. Don: (212-13)

SUMMARY

Silvopastoral systems using *Pinus radiata* in New Zealand, Chile, and Australia are described.

Forest-based systems are usually extensive, covering about 250 000 ha in total, and are aimed at using sheep and cattle as a silvicultural tool, to reduce fire risk, improve stand access, and also to provide revenue and spread investment risk. Such land use is expected to continue, as increasing areas of pasture are being planted in plantations and as more foresters discover the benefits. More intensive systems involving oversowing forage legumes and electric fencing have been successfully applied to reduce specific weeds and to improve tree growth. Silvicultural regimes vary considerably between the three countries; from relatively open "direct sawlog" regimes, which facilitate understorey grazing, to more traditional multiple thinning regimes, where grazing is soon excluded by canopy closure.

More intensive farm-based systems are well represented in New Zealand as a means of diversifying farm income, and also for soil conservation. These consist of widely spaced trees in plantations, and as shelterbelts managed for timber production. Widely spaced trees are also being planted on to pastoral farmland in Australia, particularly to prevent increasing soil salinity. However, silvopastoral systems with radiata pine are a specialised, capital- intensive land use, and the forest industry is expected to continue to be the main user of the concept.

Keywords: Agroforestry, silvopasture, *Pinus radiata*, cattle, sheep.

INTRODUCTION

As world timber supplies from natural forests are becoming exhausted or are being increasingly conserved, plantations are assuming more importance. Fast growing plantations in the Southern Hemisphere temperate zone have made a significant contribution to regional wood production, largely owing to one outstanding species - *Pinus radiata*. Chile has over 1.4 million ha of plantations (86% radiata pine), New Zealand 1.2 million ha (88%) and Australia 0.9 million ha (70%). Radiata pine is grown between latitudes 32°S and 46°S, at altitudes between sea level and 800 m, with annual rainfall between 600 mm and 2400 mm. Mean annual increments for tended stands are typically in the range 16-22 m^3/ha, and final yields of 400-700 m^3/ha are achieved in 25-35 years. The current harvest of about 26 million m^3/year from these three countries can be expected to increase to about 60 million m^3/year as existing plantations mature.

These plantations have been demonstrated, over the past 70 years in New Zealand and 30-40 years in Australia and Chile, to be sustainable, profitable, and to provide a wide range of products, from wood pulp to high quality timber, depending on the site and the management they receive.

Prior to the 1970s, pine plantations were managed under traditional forestry regimes, with livestock generally excluded from the forest. Managed silvopastoral systems using radiata pine were first considered in New Zealand in 1969, as a result of developments in plantation forestry with "direct sawlog" regimes. Under such regimes, the stand is kept more open by being thinned to a final crop of 200-250 stems/ha after pruning. Grazing with sheep and cattle was considered an opportune way of utilising the undergrowth and also of getting an early financial return, particularly where trees were planted on to pasture and where much of the farming infrastructure such as fencing already existed.

In New Zealand, Chile, and Australia the grazing of plantations is now relatively commonplace because the system has been shown to produce practical benefits, and also because areas of ex-farmland are increasingly being recognised as the most profitable sites for afforestation.

Two situations are commonly identified:

- Forest-based agroforestry, where grazing is ancillary to plantation forestry. This is usually termed "Forest grazing"
- Farm-based agroforestry: where widely-spaced trees in plantations are integrated with existing livestock farming, usually only on a part of the farm; or where trees are confined to single or double rows along existing fences, and are managed for both timber and shelter (Timberbelts).

The boundaries between these applications can become rather blurred, especially in New Zealand, where there is little difference between conventional "direct sawlog" regimes and agroforestry regimes on farmland. In Australia, pruning is uncommon and as most plantations are managed under a multiple production thinning schedule, agroforestry regimes incorporating pruning, wide spacing, and early thinning are a distinctive innovation. The term "agroforestry" is usually reserved for such farm-based plantations in that country. In Chile, plantation regimes are moving towards the New Zealand example, but stands usually incur at least one production thinning.

FOREST-BASED AGROFORESTRY

There are two main approaches - the first, which is common in all three countries, is to graze an existing understorey forage resource within a plantation, such as occurs when pastoral land is planted in pine. The second is where a forage resource is created by oversowing improved pasture species on to cutover forest sites, or into young plantations. So far this technique has been applied only in special circumstances, rather than as a general treatment.

Grazing existing pasture in forests

In the past, plantation forestry has often been relegated to land unsuitable for agriculture (Fenton 1965). More recently, there has been a marked trend towards new plantations being established on land that was previously in pasture. In Australia and New Zealand this is partly because of opposition by conservationists to the clearing of indigenous forest for plantations, but in all three countries there is increasing awareness that such pasture sites represent the most profitable sites for afforestation.

It is now widely recognised that trees grow better on land which was previously sown in legume/grass pastures, and grazed (Skinner and Attiwell 1981, Knowles and West 1986). Pasture land which is of easy terrain, free of serious weeds, close to export ports or utilisation centres and serviced by existing roads, can be a very attractive proposition for afforestation, even when the purchase price of the land is taken into account (Knowles and West 1988).

The main objectives of grazing existing pasture within a forest are to reduce the fire risk, to improve stand access and prevent ingress of scrub weeds, and to earn revenue from livestock. Typical management systems are described below

Chile

Ex-farmland which is purchased for afforestation is located mainly in the central valley or on the Andes foothills, and is usually grazed or cropped until it is planted. On good quality land, plantation forestry is not subsidised and so a low-cost regime is adopted. This involves planting fewer trees than normal, and is therefore ideal for agroforestry. On easy terrain, wheat can be sown or hay can be harvested between the tree rows, which are usually spaced at 6 m x 2 m (833 stems/ha) or in double rows 2 x 2 x 6 m, the latter being thinned inwards leaving the 6 m row clear of slash (i.e. debris).

Common desirable pasture species are rye grass (*Lolium perenne*), white clover (*Trifolium repens*), cocksfoot (*Dactylis glomerata*) and subterranean clover (*Trifolium subterraneum*). *Agrostis tenuis* and *Holcus lanatus* are also common, but are generally regarded as less desirable. After the hay is harvested, cattle are grazed to clean up the pasture along the tree rows and other areas where it has not been cut. Livestock are generally removed in mid-summer when conditions are typically very dry and are reintroduced the following winter, a year after planting. Livestock stocking rates vary considerably, but an average property of 700 ha supports 100 cattle and 1000 sheep overall. Cows and heifers are preferred to bulls or steers, because less physical damage is done to the young trees. Beef breeds such as Hereford, Angus or dual-purpose German Friesians are preferred to milk breeds.

The above operation is repeated in the second year, and again care is exercised to avoid overgrazing, which results in excessive browsing and damage to the stems.

By the third year, pines are usually well established (over 2.5 m in height) and grazing is less constrained, but livestock still need to be treated for external parasites to prevent them rubbing against the trees. Stands holding in excess of 1000 stems/ha are thinned to this stocking by slasher in the third year.

At age 4-5 years, the stand is thinned to waste to 700 stems/ha and pruned to half height. Pruning continues at 2 year intervals on a reduced number of trees until stand age 10-11 years so that the final crop of 250 stems/ha is pruned to 7-8 m. At ages 12 years, and 15 years, the stand is thinned for pulpwood. The aim of the final crop is to produce high quality sawlogs. The silviculture schedule of Forestal Arauco (one of the largest forest companies) on agroforestry sites is shown in Table 1 under the heading Chile.

Table 1 - Typical silvicultural regimes for radiata pine plantations on ex-pasture sites

	New Zealand	Chile	Australia
Initial stocking stems/ha	800	1250	1390
1st thinning - Ht of stand	5.5 m(W)	3 m (W)	17-20 m (P)
stems/ha after thinning	200-250	1000	620
2nd thinning - Ht of stand	N A	5 m (W)	23-26 m (P)
stems/ha after thinning		700	370
3rd thinning - Ht of stand	N A	15-18 m (P)	28-30 m (P)
stems/ha after thinning		350	200
4th thinning - Ht of stand		21-23 m (P)	
stems/ha after thinning		250	
Pruning 1st lift - Ht of stand	5.5 m	5 m	N A
Ht of pruning	2.5 m	2.5 m	
stems/ha pruned	200-250	700	
2nd lift - Ht of stand	8 m	8 m	
Ht of pruning	4.3 m	4.8 m	
stems/ha pruned	200-250	350	
3rd lift - Ht of stand	10 m	10 m	
Ht of pruning	5.8 m	6 m	
stems/ha pruned	200-250	250	
4th lift - Ht of stand	N A	12 m	
Ht of pruning		7.2 m	
stems/ha pruned		250	
Final crop stems/ha	200-250	250	200
Rotation age (yrs)	28-30	24-27	35

(W) = Waste thinning (no wood production)
(P) = Production thinning.

Sheep (Corriedale and Romney, often mated with a Hampshire or Suffolk ram) are generally confined to the better quality land. Predation by pumas and dogs, and also theft, is a constant problem so sheep are penned every night except during lambing, or left with a night watchman, which increases costs. Nightly penning can also introduce animal health problems, particularly infectious ovine foot-rot, and increase both internal and external parasites. Sheep tend to be grazed in large flocks (1000-2500) which concentrates the shepherding in one area, and are confined to plantings less than 4 years old, to simplify mustering. As new farms are constantly being purchased and planted, this does not present a problem. Cattle are grazed in reduced numbers until canopy closure about the twelfth year. In general terms, cattle are easier to manage than sheep, are attacked less by dogs or pumas, and also less likely to be stolen. Fencing requirements are also less stringent than for sheep, although water requirements are much higher. Although livestock losses in plantation grazing have been much less for cattle than sheep, cattle weight gains at 100 kg/head/yr have not been spectacular because of the low-quality feed. It must be realised that no fertiliser is used, and the system is very low cost. No doubt the shelter offered by the trees, from both summer heat and winter cold, offers some benefit to the livestock.

Trials with grazing deer (fallow and red deer), llamas, alpacas and vicunas amongst radiata pine were not a success - losses to pumas, even of fully grown stags, were high, and tree damage was also excessive, except with the fallow deer when it was confined to trees which were subsequently thinned to waste.

The silvopastoral system described above is currently being applied on about 100 000 ha in Chile, involving 7000 sheep and 6200 cattle. One company alone, Forestal Arauco, grazed 40 000 ha in 1989. This was made up of 56 properties, ranging in size from 50 ha to 3250 ha. The livestock included 3500 sheep on 9 properties totalling 3650 ha, and 3200 cattle on 47 properties totalling 36 500 ha. In some cases the forest company owns the livestock but more commonly grazing is allocated to a contractor.

Australia

Moore (1987) reported that some 120 000 ha of pine plantations are grazed in Australia, mainly to reduce fire risk. In the temperate region (i.e., excluding Queensland) the area is 63 000 ha. In New South Wales, South Australia, and Western Australia, significant areas of pasture land are currently being planted in radiata pine by both State and private forestry organisations. As in Chile, pastures are grazed prior to planting, and then herbicide is applied to remove competition. Sheep are introduced after 2-3 years and cattle after 4-5 years. In the temperate zone, forest grazing is usually confined to the winter and spring.

In most plantations, understorey grazing is feasible for a few years only, as the plantations are usually not pruned, nor thinned early to waste. (Table 1 shows a typical silvicultural regime used in Australia). The dense tree stockings soon close canopy, restricting grazing of the understorey to the first 6-7 years, or to canopy gaps and road margins.

In Western Australia, a regime similar to the New Zealand direct sawlog regime is used and grazing can be continued further into the tree rotation. Grazing licences are issued annually either by public tender, or simply by allocation to an adjacent farmer.

In Western Australia a more intensive system involving early thinning, high pruning, and pasture fertilisation is practised in 100 m wide strips along public roads to reduce fire risk. Graziers are required to have their stock eat the pasture down to a height of 7.5 cm by the start of summer. Heaping of thinning and pruning debris is sometimes carried out to further reduce the level of fuels. These areas are termed 'fuel reduction buffers' but are essentially agroforestry stands.

A "softwood sharefarming scheme" has also been established in Western Australia. Interested farmers can lease land to the State for the growing of a crop of pine. Farmers are paid an annuity and the State forestry organisation is responsible for planting and tending the pines. A similar scheme is being considered in Victoria. Such joint venture agreements favour agroforestry because the farms usually have an existing livestock grazing enterprise.

New Zealand

Pine afforestation in New Zealand is also being based increasingly on pasture sites. A recent survey (Hammond 1988) indicated that some 85 000 of existing pasture in forests is grazed. Properties vary from being large (3000-4000 ha), of low livestock carrying capacity (2-3 sheep/ha), and often with a brushweed reversion problem; to small (200 ha) and of high livestock carrying capacity (10-12 sheep/ha). Initial tree stockings of 800 stems/ha are common, but the hilly terrain results in only a few areas being suitable for hay or grain harvesting between the rows. Sheep are usually introduced in the second year, and cattle from the third year after planting. As in Australia and Chile, the main objectives are to maintain or improve stand access, to reduce fire risk, and to earn revenue. A common prescription is to prune 250 trees to 2.5 m height at stand height 5.5 m, and thin to waste to a final crop of 200-250 stems/ha. A further one or two prunings at 18-month intervals lifts the pruned height to 5.8 m. Whilst such a regime appears intensive and is obviously suited to fostering understorey grazing, it should be emphasised that it is very much forestry-based, being practised on many forests where

there is no grazing (Whiteside 1990). Where markets are present, additional trees may be carried through to stand height 12-14 m, to be thinned for pulp, as is common in Chile.

Such low tree stockings and early heavy thinning are dependent on genetic improvement of the tree crop, good quality tree establishment, and pruning at the right times (Knowles 1990).

As in Australia, most forest grazing is licensed to adjacent farmers, with revenue varying widely.

Livestock are controlled either with existing fences or, where these are inadequate, with electric fencing. Grazing is usually year-round, but in very few instances is such forest-based grazing self-contained, being dependent on the grazier having access to other areas of high quality unplanted pasture to finish livestock for market. Predation or theft of livestock is not a common problem in New Zealand forests.

Grazing improved pasture in forests

There are examples in both Australia and New Zealand of pastures in plantations being established specifically for livestock grazing.

The practice was adopted on a large scale on the Donnybrook Sunkland of Western Australia in 1979. In this project, clover pasture was established at the time of tree planting, primarily to improve the fertility of the soil. Subsequently, grazing has been used to help maintain the legume component of the pasture. Jarrah forest was cleared by heaping, burning,and ploughing. Pasture was established by spreading clover seed (*Trifolium subterranean*) at a rate of 12 kg/ha. Superphosphate with copper, zinc and molybdenum was broadcast spread at a rate of 500 kg/ha with the clover seed. Maintenance dressings of superphosphate were at 400 kg/ha in year one and at 200 kg/ha in years three, five, and seven (Moore, 1987).

In New Zealand, seed of a forage legume *Lotus pedunculatus* cv "maku", has been oversown on several forests totalling 10 000 ha. (Knowles 1990). The objectives have been to increase grazing pressure by cattle to control weeds such as pampas grass (*Cortaderia* spp.) and/or to improve livestock performance which would otherwise suffer on poor quality feed, and to improve tree growth. The legume seed is sown on to second rotation stands either at the time of replanting, or within 2-3 years of tree planting. Control of pampas has been cheaper than using herbicide (Dale and Todd 1988) and significant increases in tree growth have been recorded (Knowles 1990). Oversowing and grazing may be justified, even where troublesome weeds are absent, as a forest tool to improve silvicultural access and tree growth and reduce fire risk (Brown 1988).

FARM-BASED AGROFORESTRY

New Zealand

There is a particularly strong farm-forestry movement in New Zealand, with some 65 000 ha of plantations currently attributed to private landowners and investors. Possibly a quarter of this is managed under an agroforestry system. Individual plantings seldom exceed 30% of a total property, and are usually much less than this. Although there are examples of management favouring understorey grazing which are more intensive than that found on forests (such as earlier thinning, higher pruning, or lower final crop stockings), in practice the silviculture of farm woodlots and that of large-scale forests managed under sawlog regimes are similar.

Considerable practical research completed over the past 20 years has shown that, in the long-term, farm incomes would probably rise if increased areas were planted in pine-based agroforestry. A detailed survey of private landowners (Morey 1988) revealed that 8% of landowners had established agroforestry on their farms, and 13% were intending to. This compared with 33% established and 31% intending for woodlots (where grazing was not practised, or was only incidental) and 57% either established or intending to establish shelterbelts.

It can be seen that the majority of farmers readily plant shelterbelts, and that a significant proportion are involved with, or intend planting woodlots. Although the existing or even intended applications appear relatively low for agroforestry, it is probably unrealistic to expect the figures to be much higher than this after such a short period of development.

Research and practical examples have shown that reasonable quality timber can be produced from managed timberbelts (Tombleson 1986) and this innovation represents an entry point to agroforestry for many landowners who would not otherwise consider trees as a crop. Trees are planted as single or double rows, usually along existing fencelines, and protected from livestock with a 3-5 wire electric fence. A fairly standard prescription is to plant one row of radiata pine at 2-4 m spaces, and prune this to 5-6 m height in the same way as plantations. A single row of a supplementary species is planted parallel to and 2-3 m to the windward of the pines, to block the draught which would otherwise occur.

Soil erosion on steep land cleared of indigenous forest and sown into pasture is a problem in several areas, but particularly on the east coast of the North Island. Agroforestry with radiata pine is seen as a logical land-use on these sites, and although the areas planted to date are small in relation to the problem, interest by farmers seems to be increasing.

Australia

Compared to New Zealand there has been less farm-based agroforestry in Australia, although the level of research has probably been similar (i.e., Anderson and Moore 1987; Anderson *et al.* 1988). Agroforestry research has focused on the potential of trees to reduce land degradation on farms as well as producing a crop of timber. The main forms of land degradation are salination of soils and streams, and erosion of soil by wind.

Increasing salinity is of concern over large areas of pastoral and cropping land in temperate Australia. Research has shown that widely-spaced radiata pine can lower water-table levels, thereby reducing salinity (Anon 1989).

Some farmers have established their own agroforestry areas and the Government of Western Australia is considering options which would provide incentives for farmers to practise agroforestry. Many areas, where salinity is a problem, are too dry (500 to 790 mm rainfall per year) for conventional plantation forestry and growing trees at wide spacing is probably the only way to grow timber economically.

In coastal regions of southern Australia farmers need shelterbelts to prevent erosion of soil by wind and to shelter livestock and crops. Several farmers are managing timber belts to achieve these aims and to produce a crop of timber.

Both farmers and the general community are becoming increasingly aware that trees on farms have a vital role to play in producing timber and caring for the land. Therefore, farm-based agroforestry is likely to increase greatly.

Chile

The farming sector of Chile has so far made almost no use of farm-based agroforestry. The current situation where forest companies purchase farmland for pine afforestation is expected to continue.

DISCUSSION AND CONCLUSIONS

Pine-based silvopastoral systems have been widely adopted within the plantation forestry sectors of Chile, New Zealand, and Australia. The reasons for this are that there are real benefits to the forester. These include reduced fire risk, improved stand access, increased tree growth, and generation of revenue. Situations vary from those where the grazing is of low intensity and could be described as very coincidental to timber production, to those where

significant grazing continues through the first half of the rotation, and where oversowing improved forage species provides forage of high quantity and quality. Examples of the latter situation are not yet widespread, but the success of existing examples means that more intense grazing in forests is likely.

The trend for large-scale plantations to be increasingly established on pasture sites is expected to continue in all three countries, thus providing a continuing base for forestry-oriented silvopastoral systems. The adoption of silvicultural practices such as heavy and early thinning,which tend to enhance understorey grazing is most obvious in New Zealand, least obvious in Australia, and intermediate in Chile.

Adoption of silvopastoral systems by the farming community has been slow, but a reasonable number of working examples have been established in New Zealand and Australia. With the reducing role of the State in afforestation programmes in both Chile and New Zealand, the private landowners can be expected to look increasingly to the forest companies to share their confidence about future markets, particularly for higher valued quality timber. The recent increases in value for higher quality export logs in both Chile and New Zealand have also highlighted the need for landowners to appreciate the increase in capital value of their properties made possible by diversifying into agroforestry. The scope in the three countries for adoption of silvopastoral practices by private landowners is large, but only time will tell if the potential is realised. In Australia, the benefits that agroforestry can provide by helping to reduce land degradation as well as producing an economic crop of timber, add substantial extra weight to the case for integrating trees and livestock.

In considering the applicability of the silvopastoral systems from the southern temperate zone to other species in other countries, the following points should be considered:

1. Radiata pine is a very amenable species for agroforestry. It can be established easily, and is usually beyond the reach of sheep 18 months after planting, and cattle by 3 years. It is not particularly palatable, and recovers well from either browsing or debarking damage. Within the southern temperate zone, it can be grown on a wide range of soils, climates, and management regimes. It also performs well as a shelterbelt tree.

2. Large areas of the southern temperate zone are in low- to medium-producing pastures which are considered to be less ecologically or profitably sustainable than plantations.

3. The silvicultural system used for growing quality sawlogs, particularly in New Zealand, is complementary to understorey grazing. The closest parallel would be the way poplars are grown in western Europe.

4. Plantation forestry is a costly business which also requires considerable managerial skills even when starting with pasture sites. For these reasons it has not yet been widely adopted by small landowners, nor may it be particularly relevant to developing countries.

The success of various silvopastoral systems owes much to the vigour and silvicultural flexibility of radiata pine, to the silvicultural regimes being used, to the sites being planted, and to the skills of the managers.

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7 February 1990

Voluntary Paper Summaries
Résumés de communications non sollicitées
Zusammenfassungen der unaufgefordert vorgelegten Beiträge
Resúmenes de Ponencias presentadas voluntariamente

Voluntary paper summaries have been arranged in alphabetical order of authors' names.
Les résumés de communications non sollicitées ont été disposés par ordre alphabétique des noms d'auteurs.
Die Zuzammenfassungen der unaufgefordent vorgelegten Beiträge sind in alphabetischer Reihenfolge der Autoren aufgeführt.
Resúmenes de Ponencias presentadas voluntariamente dispuestos por orden alfabético de los nombres de los autores.

EFFECT OF TREE ROOTS ON SHALLOW SEATED LANDSLIDES

Kazutoki Abe
Research Engineer
Forestry and Forest Products Research Institute, Ibaraki, Japan

Robert R. Ziemer
Principal Research Hydrologist
USDA Forest Service, Pacific Southwest Research Station, Arcata, CA U.S.A.

FDC: 116: 114.1

Many shallow landslides occur during concentrated heavy rain during the rainy and typhoon seasons. In such shallow landslides, the thickness of the subsurface soil layer to bedrock, or a rigid layer, is usually less than two meters. These landslides occur when penetrating water reduces the balance between the forces promoting sliding and those promoting resistance in the potential shear shear zone located between the soil and the bedrock or rigid layer. The effect of tree roots is to reinforce the soil by increasing the frictional resistance between soil and roots as well as providing tensile binders within the soil mass.

The purpose of our research was to quantitatively measure the reinforcement effect of roots on shear resistance and to develop a method to estimate the mechanical strength of a forest on hillslope stability. We conducted shear tests in sand that included varying quantities of roots. From these tests, a new model of evaluating reinforced shear resistance was developed. Then, the effect of tree roots in a forested hillslope was calculated using the model and measurements of root distribution.

The model predicts that a shear plane is less likely to develop within a zone where the soil is reinforced by roots. But, beyond the rooting depth of the tree, the reinforced zone terminates and the total soil shear resistance, that is, soil shear resistance plus root reinforcement, reaches a minimum. This is the depth where the shear plane would be expected to develop. As the trees grow, the extent and quantity of roots increase with a corresponding increase in root reinforcement and, consequently, total soil resistance. The most important aspect of the contribution of tree roots to preventing shallow seated landslides is the depth of root penetration.

STRUCTURE, EVOLUTION AND YIELD OF QUERCUS PYRENAICA WILLD. COPPICES IN CENTRAL SPAIN (ESTRUCTURA, EVOLUCION Y PRODUCCION DE TALLARES DE QUERCUS PYRENAICA WILLD. EN EL CENTRO DE ESPAÑA).

M. Allué & A. San Miguel.
Investigador A & Investigador principal
Departamento de Sistemas Forestales (C.I.T.-I.N.I.A.)
Apdo. 8111. 28080 Madrid. Spain.

FDC: 222.1: 176.1 Quercus pyrenaica Willd.: 547: 56: (46)

Quercus pyrenaica Willd. is a submediterranean broadleaved semi-deciduous oak whose main world area is located in the Iberian Peninsula. In Spain, its current area is about 600,000 hectares. The traditional use of Quercus pyrenaica woodlands has been firewood growing and grazing due to its great ability to resprout from stumps and roots after cutting. Therefore, most stands are currently coppices, with or without standards. In Central Spain, where this study has been carried out, it occurs mostly on hillsides and foothills.

The paper briefly describes the ecology of the species in the study area and then deals with the study of different site quality indexes for Quercus pyrenaica coppices. Standing-biomass estimation equations are also presented for single individuals as well as for stands, and relationships between the most important stand variables (number of stems per hectare, basal area, dominant height, biomass, ...) are determined.

Finally, the diametral composition of stands is studied and the evolution of the most important stand variables with age is analized.

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PHYTOCLIMATES OF SPAIN
(FITOCLIMAS DE ESPAÑA)

J.L. Allue Andrade
Investigador Principal
Departamento de Sistemas Forestales (CIT - INIA)
Apdo. 8111 28080 Madrid Spain.

FDC: 111.84: 181.1: (46)

Two new models are presented and mapped for the purpose of improving on our phytoclimatic taxonomy of 1966.

Using Gaussen-type graphs, the morphogenetic model classifies the limited types of thermal and precipitation curves to be found on the Earth and their degrees of intersection, all in accordance with values corresponding to actual breaks in phytological continuity. This taxonomy is presented in the form of keys generating a periodic system, and is illustrated with a world map showing most types by means of graphic symbols. It is effective for the prediction of broad phytological types and on any chorological scale.

The integral model consists of a more sensitive numerical taxonomy based on the establishment of predictive biunivocities:

$$e_{i,P} \rightleftarrows F_P$$

where i is each of the precincts within a supra-annual 14-dimensional climatic space, corresponding to each of the chosen phytological attributes; P is a climatic point whitin this space; $[e_{i,P}]$ is the set of scalar numerical attributes defining the degree of adjustment of P to i; and F_P is the phytological feature considered in P. Relatively small modifications in the i precincts can give rise to a different set of separate, mutually supplementing ambits which further allow for the introduction of qualitative taxonomy of true values and their trends, and the mapping thereof. This taxonomy may be applied not only to the supra-annual compendia ($t \geq 13$ years) for which it was designed, but also to annual events, provided not less than 13 are assembled at a time and the frequency of each type is specified. Given these conditions, the arrangements of types obtained through the supra-annual numerical and qualitative systems often coincide both mutually and with orders of frequency in time and cartographical vicinity. This lends our cartography a rather novel dynamic character.

The model as devised is for Peninsular Spain and the Balearics, with numerical programs (both computerized and manual), qualitative keys, analytical spectra of main sites-besides Walter-Gaussen climodiagrams-, a 1:1,000,000-scale subregional phyto-climocartogram (subregions and transects, sites, climodiagrams, vegetation), a 1:1,000,000-scale morphogenetic phyto-climocartogram, an orientative chart of correspondences, plus sundry other data.

ELEMENTAL CYCLING IN A EUCALIPTUS GLOBULUS PLANTATION OF SW SPAIN (CICLO BIOLOGICO DE ELEMENTOS BIOGENICOS EN UNA PLANTACION DE Eucaliptus globulus DEL SW DE ESPAÑA)

Manuel López Arias
Coordinador de Area
Departamento de Sistemas Forestales (CIT-INIA)
Apdo 8111 28080 MADRID (SPAIN)

FDC: 181.3: 238: 176.1 Eucalyptus globulus Labill.: (46)

Since 1980, uninterrupted research have been carried out in some eucalipts plantations in Huelva (SW Spain). The objetives of this work were to analyze the main features of the Soil-Tree-Atmosphere interaction in order to answer some salient questions about the hydrology regime and nutrient cycling.

Some analysis of unpublished data related to intrasystem cycling are shown here.

The major site and stand characteristics are:

FOREST TYPE	Eucalyptus plantation
SOIL TYPE	Slightly acid sandy clay
PRINCIPAL PLANT TYPES	Eucalyptus globulus
YEARS	1981-1985
INITIAL PLANTATION DENSITY	660 trees per ha.
PRESENT LIVING TREES	567 trees per ha.
MEAN BREAST HEIGHT DIAMETER OVER BARK	17.4 cm
AVERAGE TOTAL HEIGHT	17.1 cm
BASAL AREA	15.1 m^2/ha
TOTAL ABOVEGROUND BIOMASS WEIGHT	158.3 Tm/ha
LEAF WEIGHT	11.5 Tm/ha
LEAF AREA INDEX	3.95 m^2/m^2
CURRENT TOTAL BIOMASS INCREMENT	9.6 Tm/ha/year
LEAF-FALL	3.5 Tm/ha/year
TOTAL LITTER-FALL	5.3 Tm/ha/year

Data refers to measured amounts, increments and fluxes of biomass and major elements (N,P,K,Ca,Mg) of the foollowing compartments:

- OVERSTORY (Trees forming the main canopy, including separated information on leaves, fruits and flowers, branches (wood and bark), bole (wood and bark), standing dead, etc).
- SOIL TOP ORGANIC
- TOTAL ROOTS, ETC.

The analysis is aimed to describe and characterize:

Nutrient allocation in Eucalyptus
Aboveground nutrient return from vegetacion
Mass balance of the plantation nutrient cycle

(Research supported by INIA/ R.P. n. 8149)

EVIDENCE ON THE ROLE OF CLIMATE CHANGE IN FOREST DECLINE

A.N.D. Auclair
Research Scientist
Forestry Canada, Laurentian Forestry Centre
Sainte-Foy, Quebec, Canada

FDC: 111.83: 181.222: 422.1

A marked relation was evident between climate warming in the northern hemisphere and forest decline. The onset of widespread crown dieback in 1925, 1937 and 1981 on tree species of Northern Hardwoods in eastern Canada related closely to episodes of rapid increase in global temperature. A theory was proposed based on literature evidence linking warm years to variable winter weather.

Detailed analysis of the erratic 1981 winter and spring in southern Quebec indicated that chronic xylem cavitation injury to Acer saccharum resulted from extreme thaw-freeze stresses combined with desiccation at a time of persistent soil ice in late spring. Similar patterns were noted in the winter of 1936 coinciding with extensive crown dieback on Pinus monticola in northern Idaho and in the winter of 1978-79 preceeding dieback on Picea abies over Central Europe. These facts suggested strongly that a freezing-cavitation-dieback mechanism may be universal in declining trees.

Massive cavitation had been observed on declining Betula alleghaniensis in Canada and was consistent with ecological characteristics and symptoms of crown dieback reported in the literature.

The goal of further work is the construction of a climate-driven simulation model to assess the potential risk of forest dieback under future climates. The prognosis for warmer, but more variable climate in the near term (2 x CO_2) has strong implications for forest decline as an important mechanism in vegetation change.

RATTAN TRADE AND INDUSTRIAL DEVELOPMENT IN INDIA: FUTURE RESEARCH STRATEGIES

K.M. Bhat and P.K. Muraleedharan
Divisions of Wood Science and Economics, Kerala Forest Research Institute, Peechi 680 653, Kerala, India

FDC: 287: 741: (540)

In India, with four genera and about 48 species, rattans are distributed in three major regions, viz. Western Ghats (South India), East and Northeastern India and Andaman and Nicobar Islands. Recognising their importance in the development of rural industries (mainly furniture, walking stick and handicraft items and basket-making) they have been recommended for experimental cultivation in Indian forestry even before the three or four decades. During the period between 1950 and 70s, except baskets, most of the rattan products entered the world trade for export,mostly to Middleeast, Europe and North America, earning considerable foreign exchange for the country. During the same period, the value of the rattan import from Southeast Asian countries is also considerable. However, there has been a drastic decline in both export and domestic trade from the begining of the 1980s due to overexploitation of the resources. With the raw material scarcity, Kerala state, like many other states in India, is increasingly becoming dependent on the import of rattan from other states/ countries. The recent ban on both extraction and inter-state export has threatened the existance of this traditional industry, which has been the bread and butter of many socially and economically weaker sections of the society.

Due to lack of appropriate processing technology and grading rules/standards, Indian rattan products do not compete in quality with the products that enter the world trade from many Southeast Asian countries. The existing technology seems to be highly labour-intensive and primitive . Mechanisation is not found even in the minimum scale to meet the quality demands of both domestic and internationl markets.

Attention is directed to review the recent rattan trade to evolve the future research strategies for efficient utilization and resource management. The major areas of research needs are: developing inventory techniques including taxonomic studies and live-collection, standardisation of propagation / planatation techniques, developing appropriate technologies for harvesting, and industrial processing especially curing, drying, conversion, post-harvest protection, establishing grading rules / standards and trade names for raw material classification and quality assurance of the products in the trade. It is also important to work out the cultivation economics and evaluate the socioeconomic constraints for introducing improved technologies and the impact these new technologies on the living conditions of the rural people. Recently a multidisciplinary project has been initiated by the Kerala Forest Research Institute to face the challenges and at this juncture international cooperation is sought for the technology transfer among rattan growing countries.

GLOBAL WARMING'S EFFECT ON THE FOREST/AGRICULTURE INTERSECTION IN THE U.S. MIDWEST

M.D. Bowes, R.A. Sedjo, N.J. Rosenberg
Resources for the Future

FDC: 111.83: 422/423: 62: 91: (73)

Despite many uncertainties, the continued accumulation of carbon dioxide seems likely to cause the lower layers of the atmosphere to warm. Climate changes of the kind suggested by global climate models would have profound affects on our natural resource systems and regional economies. In particular, agriculture and forestry would be affected in important ways. Accordingly, it is essential that the impacts of climate change be carefully assessed and possible responses to them analyzed as a means of evaluating options for those will deal with the impacts.

Participants in the Climate Resources Program at Resources for the Future are engaged in developing a methodology to accomplish some of the above-stated objectives. Not only are the first order physical and biological effects of climate change on a region's natural resources considered, but also their possible ramifications on the broader economy. The process makes provision for assessing the efficacy of specific responses to climate change. The study area is a four states region of the midwestern United States, including the states Missouri, Iowa, Nebraska and Kansas. Across most of this region, agriculture is the natural resource industry of primary importance. Forestry, however, is the primary resource-based industry in much of southern Missouri.

The focus of the investigation described here is the forests of the southern half of Missouri. In that area of rather rugged landscapes and lower productivity soils, forestry is the dominant land use, with agriculture largely represented by small farms producing livestock or hay. The growth and species composition of forests at three Missouri locations have been simulated using a forest ecological model (FORENA), examining forest development under a variety of climate warming scenarios. We find that any significant future warming (1°C or greater), unless associated with considerably increased precipitation, could lead to severe and rapid declines in the forest. Hypothesized beneficial effects of elevated CO_2 levels, through increased photosynthesis and reduced transpiration, do not appear to be sufficient to offset this predicted forest decline. It is not unexpected that the forests of Missouri would be particularly sensitive to climate change, since this is the present transition zone between the eastern hardwood forests and the midwestern prairies.

Possible responses to the impacts of climate change include reforestation with more adaptable species and increased management of the standing forests. The paper concludes that these strategies do not appear to be practical for the Missouri hardwoods forests, which offer little economic return to active planting or management. With the forest decline, timber using industries may be expected to decline also. An increase in salvage-logging, and some adaption in product mix, might temporarily postpone the eventual industry decline. Despite declining forest productivity, significant land use shifts between agriculture and forestry, resulting from climate change, would appear unlikely. Some increase in grazing use seems most likely.

A HEIGHT COMPETITION INDEX USEFUL IN MIXED STANDS

P. Braathe
Professor Emeritus
Division of Silviculture
Norwegian Forest Research Institute, Aas, Norway

FDC: 561.1: 181.41: 228.3--01

In regenerations and young stands with two species mixed together, it is important to know how one species influences the development of the other one.

The diameter increment is known to be rather sensitive to the competition from the neighbouring trees. Height increment is also influenced, but to a lesser degree. It is known from spacing experiments that height growth of Norway spruce (Picea abies) is little influenced within a wide range of stand density. For some broadleaved species height growth is even stimulated in dense positions.

When the height of trees is different the height increment will be influenced by competition both within a species as well as between species.

Based on experiments started i 1975 in 14 research areas in Norway the reduction of height increment of young Norway spruce by competition from birch is found to be considerable. The birch trees were higher than the spruce but of the same age.

The reduction is estimated by using a height-distance competition index for the single trees, which all were located by coordinates. This height-distance competition index (HCI) is the height difference between birch and spruce divided by the distance between the trees and summed up within circles of 3 m radius at the beginning of each 5-years period. The relation between the relative height increment (RTH) and the index is calculated as RTH = a + b ln(HCI + C) with values of C between 1 and 15.

The investigated areas fall into two groups, dominated by Betula pendula (A) and B. pubescens (B) respectively. The equation RTH = a + b ln(HCI + 2) gave the highest R^2 = 0.448 in group A, and RTH = a + b ln(HCI + 8) the highest R^2 = 0.204 in group B.

This height-competition index is expected to be useful in the future investigations on development of mixed birch - spruce stands and possibly for modelling and prognosis.

ECOLOGIA Y MANEJO DE MATORRALES DE COSCOJA
(QUERCUS COCCIFERA L.) EN ESPAÑA
(Ecology and management of Quercus coccifera L.
shrublands in Spain)

I. Cañellas
Investigador
Departamento de Sistemas Forestales, CIT, Instituto Nacional de
Investigaciones Agrarias (I.N.I.A.), Madrid, España.
FDC: 18: 176.1 Quercus coccifera L.: 91: (46)

La coscoja (Quercus coccifera L.) es una de las especies arbustivas forrajeras más importante de la Región Mediterránea. Cubre cerca de 2 millones de ha. en masas puras o mezcladas con otros arbustos perennes esclerófilos, además, 12 millones de cabras y gran número de animales silvestres dependen de este arbusto para sastifacer parcial o totalmente sus necesidades alimenticias.

Se distribuye por toda la cuenca mediterránea, aunque se encuentra ausente en la mayor parte de Italia. En España, estos matorrales corresponden a los climas mediterráneos bien definidos, desde el meso al xeromediterráneo, entrando en zonas áridas por un lado y pudiendose encontrar muestras de tapiz continuo de coscoja en áreas submediterráneas.

Estos matorrales se encuentran dentro del orden Pistacio-Rhamnetalia alaterni, el cual resume la vegetación fruticosa esclerófila o de monte bajo mediterráneo y su procedencia suele deberse a la degradación de bosques con especies esclerófilas, subesclerófilas y pinos xerófilos, debido principalmente a una combinación de roza, incendios, cultivos itinerantes y pastoreo excesivo. Pero también podemos encontrarnos con masas que son climax regionales o locales.

La conservación de estas masas está orientada a la protección del suelo contra la erosión y la producción de alimento para el ganado cabrío principalmente y fauna silvestre (en muchas de estas áreas la fuente de ingresos proviene mayoritariamente de una ganadería extensiva y de la caza).

Los usos alternativos de estos matorrales son los de la eliminación del material arbustivo, para fines ganaderos, con el consiguiente aumento de pastos, o para la repoblación con otras especies leñosas más productivas, generalmente con pinos xerófilos (Pinus halepensis Mill.) y en algunas ocasiones con encina (Quercus rotundifolia L.). En la mayoría de los casos, estas dos actuaciones están limitadas tanto por el costo económico que suponen, como por las bajas productividades de estas áreas. Por lo que su aplicación dependerá de las condiciones ecológicas de la superficie donde se quiera actuar.

THE HYDRO-ECOLOGICAL EFFECTS OF THE MOUNTAIN FOREST SOIL

Zhou Chong-guang, Professor
Honourary Director of Zhejiang Forestry Institute
Hangzhou, China

FDC: 116.2: 114.12: 114.35/.38: (23)

In 1986-87, I investigated the forest soil water conditions in Tianmu Mountain with some of my colleagues. With its peak over 1500 m above sea level, this mountain is the sources and water-shed of many streams of Yangtze River and Qiantang River. There are four vertical forest vegetation zones, which include seven forest groups within different altitudes. The seven forest groups are: evergreen broad-leaved forest, evergreen and deciduous broad-leaved mixed forest, deciduous broad-leaved forest, hill-top shrub and dwarf forest, needle-leaved forest, needle-leaved and broad-leaved mixed forest, and moso bamboo forest.

The result of the investigation showed that the hydro-ecological effects of the mountain forest soil are different in the various forest groups.

1. The water-holding capability of forest litter is strongly affected by the standing crops, the component, and natural moisture content. The average value of water-holding capacity in different forest groups is 39.59 ton/ha (from 55.72 to 25.65 ton/ha).

2. There are certain rules in the main physical properties of the forest soil (mineral horizon) within the depth of 60 cm of different forest groups in Tianmu Mountain.

1) Specific volume and specific weight usually increased according to the deepness of the soil. When the forest soil is in natural condition, the value of the specific volume is always less than one. But it will be larger than one, when the soil is disturbed by other beings.
2) The forest soil porosity in natural condition decreases with the depth of soil. But if the soil structure is destroyed, it will be changed.
3) The hygroscopic moisture and capillary humidity have a tendency to decrease according to the depth of soil. This natural rule will be changed if disturbed.
4) The natural moisture content increased in accordance with the soil depth. But variation occurs when soil is interferred.

3. The water-holding capacity of forest soil is mainly controlled by its porosity. The soil capillary porosity in different forest groups is always larger than macro-porosity. The total water-holding capacity of forest soil is in proportion to its porosity. The water-content of forest soil is usually greater than non-forest soil (as grassland).

4. The mean value of the total water-storage (including the forest litter) of the forest soil within 60 cm depth in different forest types in Tianmu Mountain is 3,978.15 ton/ha (397.82 mm/ha), which is about 24.09% of the mean annual precipitation, 1,651.15 mm, from the foot to the peak of the mountain.

TIMBER STAND IMPROVEMENT: AN INTENSIVE SILVICULTURAL APPROACH FOR IMPROVING THE PRODUCTIVITY OF SUB-TROPICAL HARDWOOD STANDS IN TAIWAN

Hsu-Ho Chung
Head, Division of Forest Management
Taiwan Forestry Research Institute, Taipei, Taiwan, ROC

FDC: 238; 228.82; 176.1; (213)

An intensive silvicultural practice of selective cutting and natural regeneration was applied to the old growth of sub-tropical hardwoods which have been selectively logged for high grade timber and, thus, was poor in species composition. The approach used here was to remove trees with undesirable characteristics and, then, allow natural regeneration to take place in space thus created by selective cutting. In some cases planting as well as prunning of desirable trees left in stands also practised in our approach. The ultigoal of the approach reported here is to create multi-layered stands which will be managed, sustained and perpetuated by selective cutting and natural regeneration.

Four to twelve years after treatments survey of the trial stands showed that the average annual growth of the treated ones were 1.4X to 14X higher than that of untreated controls depending on the sites and conditions of stands, treatments applied and the duration after treatments. Likewise, the increment percent of treated stands were 2.5X to 13X that of the untreated ones. The treated stands, in genersl, have more uniform diameter distribution and better species composition than the controls. Although, admittedly, this silvicultural measure is a costly one its operation costs, however, can be well balanced by the income generated from timber sales of removed logs, by the planting saved, by the value of stands raised and by the benefits of avoiding severe erosion which othersies would occur after stands are clear-cutted.

Overall, this approach appears to be a very promising alternative to the clear cut - planting practice which normally applied to the management of hardwood stands here in Taiwan. This silvicultural practice, we believe, also have the potential of being applied to the long term conservation of natural hardwoods in wet tropics.

EFFECTS OF LIMING AND FERTILIZATION ON THE FUNCTIONING OF A SPRUCE ECOSYSTEM : RELATIONSHIPS TO FOREST HEALTH IMPROVEMENT

Mohamed Ahamed DALDOUM *

University of Khartoum
Faculty of Agriculture Department of Forestry
Shambat, P.O. Box : 32, KHARTOUM North (SUDAN)

FDC: 181.45: 425.1: 425.3: 237.417: 174.7 Picea abies Karst.

The effects of an application of liming material and/or fertilizers on the state of health in declining Norway Spruce (*Picea abies* KARST) stands in the French Vosges have been studied and the induced soil modifications, as well as the general functioning of this ecosystem have been analyzed.

The main results are as follows :

- The application of limestone, magnesium lime and/or fertilizers (treatments Ca, CaMg, NPK CaMg) on a very acid soil has caused, 4 years after application, important modifications in this soil. Moreover, the comparison between these treatments shows that the efficiency depends on the solubility of the liming material and to a greater extent on the associated anions (e.g. sulfate, nitrate, carbonate, or hydroxyl). The soluble fertilizers (treatments KMg, SMg) were less efficient, and they have slightly desaturated the soil, which could mainly be attributed to the "anion effect".

- The analysis of the precipitations arriving above the canopy shows that the rains are slightly acid (pH 4,7) and very diluted, with sulfate and nitrogen compounds as the dominant ions. The throughfall solutions are enriched in major elements which could originate either from dry deposition, or biological transformation in the canopy or from the combination of both them. The solutions are more acid than the rain water (pH 3,9). In the mineral soil, the geochemistry of the percolating solutions is largely dominated by aluminium nitrate. This implies that most of the aluminium is in inorganic form. That result is however different from what is known for podzolic soils, where the aluminium ion is generally complexated by the organic matter.

- Liming and/or fertilization modify the geochemistry of the soil solutions, by increasing the pH of the soil solutions and the base cation saturation. Therefore a considerable amount of soil water acidity is neutralized and the molar Ca/AL or Mg/AL ratios are remarkably increased.

- The amelioration of the stand health is probably due to the favourable action of liming materials, as well on the solid phase as on the solutions of the soil.

Moreover it is of a great interest to examine the trends of a long-term action of these liming materials on the soils and their effects on the state of health of the stands.

Key words : fertilization, liming, atmospheric inputs, thoughtful, lysimeter, soil solution, forest ecosystem, acidification.

* Present address : INRA, Champenoux, F-54280 SEICHAMPS, France.

A STUDY OF THE BIRD COMMUNITY AT THE KHOJIR NATIONAL PARK

A. Dayani

Professor
Faculty of Natural Resources
KARADJ, Iran

FDC: 152: 148.2: (55)

The bird community at the Khojir National Park (35° 40' N, 51° 45' E) was studied by direct observation, by capture-recapture and by the application of mist nets. All captured birds were ringed and their measurments were taken before releasing them into their habitats.

Over 100 ressident and migrant species were identified through out the park. The highest number of species was observed along the Jarroud river bank.

Birds as Magpie (*Pica pica*), Syrian Wood Pecker (*Dendrocopos syriacus*), Chukar Partridge (*Alectoris chukar*), See-See Partridge (*Ammoperdix griseogularis*) and House Sparrow (*Passer domesticus*) were residents of the park. The first two species live solitarily and the latter three species in groups.

Large Rock Nathatch (*Sitta tephronata*) is a very abundant species in the park and its repeated capture - recapture confirme that it is a resident of the park.

Surrounding the consequences of watershed disasters in the periphery of the Indian triangle*

Rohan Ekanayake
Research School of Social Sciences
Australian National University
Canberra

Summary

FDC: 116.2--090.3: (540)

The watershed of the 'Indian triangle' is formed by the flow of two mighty rivers which emanate from the Himalayas. The Ganges and Brahmaputra embrace the lands and peoples of Nepal*, India*, and Bangladesh* before emptying into the Bay of Bengal. A recent monsoon submerged two thirds of the low lying Bangladesh rendering 25 million people homeless. Can the future of these people be secured by the lowering of water levels downstream? What effect will the continuous removal of *natural barriers* to the rains in the upper regions have on policy? These are some of the dynamic issues that will be addressed in this paper considering the prospects for sustainable development and ecological stability in these watersheds.

Watershed Concerns and Recent Policy Formulations in Sri Lanka and Australia: a developing and developed country comparison

Rohan Ekanayake
Research School of Social Sciences
Australian National University
Canberra

FDC: 116.2--090.3: (548.7): (94)

While accomodating a similar population to Australia, Sri Lanka in its tiny 270 miles stretch, has its people clustered on the moist southwestern third of the island known as the 'wet zone'. In Australia, where the main concentration is in the eastern part of the continent, there is heavy reliance on the catchments of the Great Dividing Range and the associated run-off, for agriculture and hydro electricity. In Sri Lanka, the catchments for nearly all its rivers rest in the central highlands where most of its hydro electricity is generated and water diverted for downstream purposes. Compared to Australia, Sri Lanka receives a relatively higher rainfall mainly from the monsoons due mainly to activities in the Bay of Bengal.

Irrigation structures in the dry zone of Sri Lanka has a history of 2000 years, and thus, its first water management practices can be related to that time. However, in modern Sri Lanka, soil erosion and watershed problems were first recognised and addressed in the legislature in the early 1940's. But policy formulation did not take place till recent times before a major river basin development programme was initiated surrounding the Mahaweli river. Towards the sustenance of this programme it was inevitable some policy be introduced at some stage to manage natural resources surrounding the water catchments. This materialised only in the late 1989 when an interim report on watershed management was considered in the legislature in Sri Lanka.

The relevant legislation were first introduced in Australia in 1940, and its maiden water resource assessment programme began in 1963. Australia's main water management programme involves the Murray-Darling river basin that spreads over four of its major states. More recently, a Bill was introduced to the New South Wales legislature to implement total catchment management of the State's natural resources, namely, the co-ordinated and sustainable use and management of land, water, and vegetation resources on a water catchment basis.

While deforestation in the catchments is common in both countries and excessive pressure on the water resources, there is genuine concern in Sri Lanka and in Australia to ameliorate the situation and achieve a *balance*. In this paper, an assessment of the watershed policies of both countries will be carried out drawing attention to specific economic, environmental and socio-cultural considerations in the past decades.

LAND CLASSIFICATION OF SPAIN: A FLEXIBLE SCALE MULTIFACTOR FRAMEWORK FOR FORESTRY PURPOSES (Clasificación territorial de España: un sistema de escala flexible para aplicaciones forestales)

R. Elena-Rosselló and G. Tella
Investigador Principal and Técnico de Investigación
Departamento de Sistemas Forestales, CIT, Instituto Nacional de Investigaciones Agrarias (I.N.I.A.), Madrid, Spain.

FDC: 91--014: (46)

A nation-wide Land Classification of Spain useful for renewable resources assessment, inventory and research, has been developed at I.N.I.A. after several successful experiences carried out at regional level. The construction of this classification mainly aimed to provide a land model based on physical factors with undoubted forestry significance that are non-changing at human life span.

Because of the size of Spain (504.750 Km2.), its ecological diversity and available cartographic information, we had to design an original land classification method showing the following features:

a) Divisive hierarchical multifactor framework in four progressive phases with increasing resolution power (25, 4, 1 and 0.25 Km2 sample size) and source map scale (1/400.000, 1/200.000, 1/50.000 and 1:10.000), and decreasing land coverage in accordance with land variability.

b) Climatic, geological, and physiographic attributes actively used in land classes definition process, and biological, current land use, soil or remote sensing information passively used as land classes test.

c) Twinspan multivariate analysis applied in order (1) to detect the main existing multifactor gradient (2) to arrange and classify the sample squares (3) to identify squares throughout the analysed land using a reduced number of indicator attributes.

In the first phase, an ecoregionalization process took place, and eight main ecoregions were defined and delimited by means of 570 sample squares of 25 Km2 size, characterized with 174 climatic, geological, and physiographic attributes. The resulting ecoregions showed highly significant correlation with phytosociological taxa distribution. The second phase has been developed separately for each ecoregion. After its completion, 260 Land Classes have been defined using a sistematically selected sample of 5450 squares of 4 Km2. Afterwards, 125000 squares have been identified and all the Spanish Land Classes were mapped and forestry characterized by means of an Arc-Info Geographical Information System.

The obtained framework can be used in different scale forest studies. At present, it has been successfully used in studies on native and non-native forests (*Pinus nigra* plantations, *Quercus suber* woodlots, etc..). Important ecological and silvicultural features have appeared highly dependent on the Land Classification. As a consequence, land suitability maps for different forestry purposes have been designed.

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The Austrian Forest Soil Monitoring System

M. Englisch, F. Mutsch, W. Kilian
Federal Forest Research Station Vienna, Austria

FDC: 114.7: 114.1/.3: (436)

In connection with the Austrian Forest Damage Monitoring System (WBS), a comprehensive investigation concerning the state of forests in Austria, a forest soil monitoring system has been carried out since 1987. The aim of this periodical survey is both an ecological interpretation of the WBS and an information on the state and development of the forest soil in particular.

The survey is being carried out on a systematical grid of permanent sample plots, 8,7 x 8,7 km in size. All over Austria there are 534 sample plots. In some districts this basic grid is densified by the local forest administrations. The survey is carried out strictly according to the Guidelines for Forest Soil Investigations, presented by Kilian and Mutsch in this session (invited paper S.1.02-00). The sample plots are layed out as permanent ones and it has been intended to investigate the single plots as extensively as possible. According to the intention of a comprehensive ecological investigation great emphasis has been laid on detailed field survey including plant sociological survey. Soil samples are taken from 4 layers of the mineral soil and area proportional samples from the forest floor. About 30 parameters including heavy metals and nutrient and acidification status are analysed in each layer. It will be extended to 40 - 50 parameters. Alltogether about 250 single data (plant species not included) are investegated from each sample plot. Thus, the intensity of the survey meets nearly the highest level of investigation, regarded in the guidelines mentioned.

A joint interpretation of field data, analytical data and plant sociological surveys is possible by a data system developed at the Federal Forest Research Station, Vienna.

As a first step soil stress and soil sensibility will be contrasted in order to estimate, to which degree the various soil functions are endangered. On the basis of these results more detailed questions can be answered by the existing data and by additional analysis. The experience obtained from the first evaluation will lead to more precise questions for further surveys which are to be carried out every 5 to 10 years.

Because of the identity of sample plots of this monitoring system with those of the Forest Demage Monitoring System it is possible to correlate the soil results with those of the annual single tree-crown assessement, the needle analysis, and in some places also to air pollution impact and to pathogens. The additional location of the sample plots within the grid of the Austrian Forest Inventory provides for the use of this large data pool too.

First results are being presented.

EFFECTS OF WHOLE WATERSHED TREATMENTS WITH $(K/Mg)SO_4$ AND $(NH_4)_2SO_4$

K.H. Feger, G. Brahmer, H.W. Zöttl
Institute of Soil Science and Forest Nutrition
Albert-Ludwig-University, Freiburg i.Br., W. Germany

FDC: 237.41: 116.2: 181.34

In the research project ARINUS the effects of restabilization measures (application of soluble K/Mg fertilizers) and atmospheric deposition are studied in typical spruce ecosystems in the Black Forest (SW Germany). The objective is to quantify the natural and anthropogenic components of element cycling at these sites. This provides a better estimation of the effects induced by perturbations, eg. increasing atmospheric deposition, fertilization, or biomass export. Interrelations between the terrestrial and aquatic system are assessed by a combination of flux measurements in representative plots with balances of small experimental watersheds. The paper describes approach, treatments, field installations, methods, and site conditions. Results are presented for the time prior and subsequent to fertilization.

The study is conducted in two experimental watershed areas, Schluchsee and Villingen, with contrasting site conditions and forest management history. Each area consists of a set of three small adjacent watersheds. They are uniformly stocked with managed Norway spruce plantations (45 and 100-year-old, respectively). The individual watersheds in each area reveal a very similar hydrological and biogeochemical behavior. This is a favorable condition for the evaluation of manipulation effects. Deposition in both areas is almost equal and of a low to moderate level known for the higher altitudes of the Black Forest (canopy throughfall: H^+ 0.4, S 12, and N 10 kg $ha^{-1}yr^{-1}$). According to the different site conditions, the element output from both areas differs distinctly, particularly for N and S. At Villingen, N is almost totally retained, whereas at Schluchsee N export is in the order of the input. In neither of the study areas S is retained. S export at Schluchsee exceeds deposition by factor 2. The higher N and S output rates at Schluchsee are due to the much higher mineralization of organic matter at this site.

In May/June of 1988 two of the three watersheds in each area were treated as a whole with different fertilizers. The application of 700 kg ha^{-1} $(NH_4)_2SO_4$ aimed to simulate excessive atmospheric N and S inputs. The application rate equals 10 to 15 times the annual deposition of both elements. Furthermore, $(NH_4)_2SO_4$ is an agent with a strong acidification potential depending on N transformations in the soil. 750 kg ha^{-1} $MgSO_4$ at Schluchsee and 850 kg ha^{-1} $(K,Mg)SO_4$ at Villingen were applied to counteract the insufficient supply of the stands with Mg and K, respectively. All treatments resulted in initially decreased pH and elevated inorganic Al concentrations in soil solution. In the K/Mg treatments soil solution pH recovered soon, whereas in the N treatment pH has remained on a lower level due to nitrification starting up early. Nitrification and nitrate leaching is highest at the Schluchsee site. As a consequence, inorganic Al have stayed permanently high and base cations have been leached considerably. The effects of treatments to streamwater have been hitherto moderate. 1½ years after application the export of the fertilizer elements from the watersheds did not exceed 10%. However, from the amount of Cl^- added with the fertilizer as a tracer, likewise only 25% have left the different watersheds. A considerable portion of the applied elements has been adsorbed in the soil as can be seen from soil inventories. Needle analyses demonstrate an uptake besides of N, Mg, and K, also of S.

DBH-HEIGHT AND DBH-AGE EQUATIONS FOR PINUS OOCARPA SCHIEDE IN HONDURAS

Oscar W. Ferreira

Silviculturist

National Center for Applied Forest Research (CENIFA)
SIGUATEPEQUE, Honduras

FDC: 521.2: 522.2: 568: 174.7 Pinus oocarpa Schiede--015.5

Pinus oocarpa Schiede is the most important and widely distributed pine species in Honduras. While processing information from permanent and temporary plots, it is often necessary to use a regression model relating the tree variables of dbh and total height. Besides, the data from most forest inventories with management purposes rely on age classes estimated from information on the diameter distribution.

The objective of this study was to test several equations expressing both relationships mentioned above. The data were collected from 351 trees growing in 45 permanent plots established in the province of Comayagua, Honduras. Seven and six mathematical models were tested to express the relationships between dbh and height and dbh and age, respectively.

HIGH SPEED HIGH STRESS RING SHEAR TESTS ON GRANULAR SOILS AND CLAYEY SOILS

Fukuoka, H. and Sassa, K.
(Landslide Section, Disaster Prevention Research Institute,
Kyoto University, Kyoto, Japan)

FDC: 116: 114.1: 114.462/.463

Recently, Progress of the prediction techniques on landslide movement come to be required. Sassa has developed a computer simulation method and showed that excess pore water pressure on shearing plane causes the apparent friction angle ϕ_a to decrease, and it leads to a long reach of landslide mass. In order to realize the reliable prediction of landslide movement, the friction angle of soils during motion must be measured. Using a newly developed High Speed High Stress Ring Shear Apparatus by Sassa and Fukuoka, tests on some sand, soil and clay samples including soil from two landslide sites in Japan, were executed and got following results:

1) The friction angle under moving condition (ϕ_m) increases as shearing speed (v) goes up. For Jizukiyama landslide soil, ϕ_m changes from 32°.8 to 38°.5 as the shearing speed varies from 0.01cm/sec to 10cm/sec. However, When shearing speed decreases ϕ_m tends not to decrease. One of the reason of these phenomena may be that the rate of crushing and collision between soil particles increases as the shearing velocity becomes large. And also the structure of the shearing plane and the grain size distribution will be changed and it causes the friction angle to increase.

2) Saturated and unsaturated clayey soils have different friction angles during shear. Tests on the Jizukiyama Landslide soil showed $\phi_m = 22°$ for saturated condition and $\phi_m = 35°$ for unsaturated condition.

3) When samples of high degree of saturation is quickly loaded, which simulates ground condition loaded by a high speed landslide mass, excess pore water pressure is generated and the apparent friction angle decreases. But as the excess pore water pressure dissipates ϕ_a gradually increase up to ϕ_m. The dissipation obeys the one-dimensional consolidation theory by Terzhagi and Mikasa, so the speed of dissipation, namely the increasing rate of ϕ_a is a function of the permeability and compressibility of soil. Really the rates are fast in granular soil and slow in clayey soils.

Utilization of Landsat MSS data for monitoring hazard zone in a high-altitude area with glaciers of Nepal Himalaya

Yoshihiro FUKUSHIMA and Sumiji KOBASHI
Associate Professor and Professor
Department of Forestry, Kyoto University
Kyoto 606 JAPAN

FDC: 116.7: 585: (23)

The global warming due to the climatic change caused by the increase of carbonic acid gas, fron gas and so on, may bring lots of serious disasters on the earth somewhere. One of them which is easily supposed is the increase of flood and debris flow events owing to the decrease of glacier-covered area in a high-altitude area. Someone might remember that a flood by cyclone had attacked villages down the river in Khumbu region in Nepal on October 1985. The flood is seemed to have been caused by the breaking down of terminal moraine in one of glacier lakes. It should be paid attention that a vast volume of unstable moraine still remains at the terminals of glaciers in Nepal and Bhutan Himalaya.

Langtang Valley as a study area is located in 60 kilometer north of Kathmandu, the capital city of Nepal, and is surrounded by high altitude mountain about 5,000 to 7,000 meter. The discharge and precipitation were observed at the station of 4,000 meter above sea level. The catchment area is 333 square kilometer and the glacier-covered parts occupies 38.2 percent of the total area. The observation was carried out during a year from July 1985 to June 1986. The simulated hydrograph in Langtang valley by the rising of air temperature shows a wide fluctuation. It means a increase of flood frequency.

The Landsat MSS data which was taken on November 18, 1984 and was consisted of the four channels, these were green, red and two infra-red as a wave length bound, was used for classifying the surface condition in Langtang Valley. Consequently, the surface condition can be classified into five categories, such as snow-covered glacier, debris-covered glacier, bare land, forest and water. The unstable moraine is belong to the bare land of the terminals of debris-covered glacier. It will become the sources of flood or debris flow in a heavy rainfall.

On the other hand, the digital terrain model (DTM) of square-grid of 500 meter has been made from the map of scale of 1/50,000, and the data base on the topography was completed in Langtang Valley. And the final Landsat image data in Langtang Valley has been added to the data base by the affine transformation. As such a information is easy to visualize on a computer display, it is very useful to evaluate hazard area in a high-altitude mountain area which is too difficult and large to investigate actually.

The authors would emphasize that the global warming will affect not only to developed countries, but also to developing counties, and that the primary information about hazard area is too insufficient in the latter.

IMPROVEMENT OF BIOMASS GROWTH AND PRODUCTION - THE IEA BIOENERGY AGREEMENT PROGRAMME

R. Gambles and L. Zsuffa
Faculty of Forestry, University of Toronto, Toronto, Canada

FDC: 238--01

The International Energy Agency's Bioenergy Agreement encourages cooperative, international research on biomass for energy in three areas: improvement of energy-dedicated biomass production systems, biomass supply from conventional forestry, and improvement of methods for conversion of biomass feedstocks.

In the area of biomass production systems, eight research activities are being undertaken on production systems, ecophysiology, agricultural/herbaceous crops, pest/disease management, feedstock qualities, ideotype tree, exchange of genetic material, and joint testing of stock.

DEVELOPMENTS IN TREE IMPROVEMENT PROGRAM FOR TWO PLANTATION SPECIES IN PICOP

A. V. Glori
Manager
PICOP Forest Research Department
Tabon, Bislig, Surigao del Sur
Philippines

FDC: 232.12/.13: 176.1 Eucalyptus deglupta: 176.1 Albizia faleataria

The timber production research unit of PICOP pursues a tree improvement program to augment wood densities of its two principal species, namely: Eucalyptus deglupta (Bislig provenance) and Albizia falcataria.

These species are currently used for newsprint and kraft paper manufactures.

Progress results obtained were as follows:

1. Intercrosses made between E. deglupta, E. urophylla (Flores, Indonesia), and E. pellita (Queensland) showed that E. deglupta x E. pellita cross (now, 3 years old) consistently ranked best in height and diameter which were about twice as much as any of those of the parents. Although no wood density test has been made as yet at this point in time, selection, on the bases of growth rate and resistance to any pest/disease known in the area, is in progress.

2. A technology package for raising E. deglupta clonelings obtained from superior trees has been developed, using a combination of IBA (6,000 ppm) and IAA (2,000 ppm). Consequently, a clonal garden for superior trees has been established as source of clonelings.

3. In the case of A. falcataria, 7 different provenances were tried in PICOP area, namely: Solomon Islands, Bulolo (PNG), Tabibuga (PNG), Hawaii (USA), Selangor (Malaysia) Sabah (Malaysia), and Ivory Coast. PICOP provenance was included to serve as control, After 6 years Solomon provenance attained a diameter greater than PICOP by 32%. In diameter growth no practical difference was observed between PICOP and any of the other provenances except Ivory Coast which showed to be lower by 16% than PICOP. In terms of height, Solomon provenance showed to be practically the same as PICOP. Except Tabibuga to which PICOP and Solomon were superior by about 18% in height, all other provenances were slightly inferior to PICOP and Solomon in this parameter.

INPUT AND CYCLING OF AIR POLLUTANTS AND NUTRIENTS IN BEECH AND SPRUCE ECOSYSTEMS IN THE VICINITY OF A STRONG SO_2-SOURCE (PAPER MILL)

Godt, J.
University of Kassel, Dept. Landscapeecology/
Soil Science, Henschelstr. 2
D-3500 Kassel, FRG

FDC: 181.45: 425.1: 425.3: 181.34

In the area of a municipal forest in Hann. Münden/FRG flux rates of nutrients and air pollutants in open field precipitation, canopy drip and stemflow have been measured over a period of two years in three spruce stands and one beech stand. The sites are characterized by different exposition towards a strong SO_2-source (paper mill, annual emission 6.800 t SO_2/a). Ecochemical soil conditions of all stands are characterized by high quantities of exchangeable H^+ (particularly in the upper soil layers) and Al (Fe) and low base saturation (< 20 %).

Deposition rates such as interception deposition, total input rates, and leaching rates have been calculated by using Na as a tracer element.

High total input rates for S (up to 70 kg/(ha*a) in spruce and 44 kg/(ha*a) in beech), resulting from high SO_2-interception deposition rates and high total input rates of H^+ (up to 4.3 kmol H^+/(ha*a) in spruce and 2.68 kg/(ha*a) in beech) have been found in the exposed sites. The local source is strongly influencing deposition rates of S and H^+ in the exposed stands (1/3 of total deposition rates).

Resulting from buffering reactions on the needle/foliage surfaces, high leaching rates of Ca, Mg, K and Mn are stated for both tree species (sum of 1.3 kmol/(ha*a) for beech, 1.6 - 2.1 kmol/(ha*a) for spruce stands).

As critical deposition rates for S and H^+ are exceeded by far in the vicinity of the SO_2-source, negative influences on silviculture, soil chemistry, drinking water quality and all other functions of forest ecosystems can be considered as beeing existant or can be expected in the near future. Therefore strict reduction of emissions is indespensable.

For further information see:

Godt, J. and M. Weyer (1989): Input of sulphur and acidity in three spruce stands in the vicinity of a strong SO_2-source. in H.-W. Georgii (ed.), Mechanisms and Effects of Pollutant-Transfer into Forests, 333-343, Kluwer Avademic Publishers, Drodrecht

Godt, J. (1989): Vergleich der Säurebelastung und des Puffervermögens von zwei Buchenaltbeständen an Standorten über Kalk und über Buntsandstein. Allgemeine Forst Zeitschrift 29-30, 776-778

STRUCTURE AND YIELD OF CORK OAK (*QUERCUS SUBER* L.) STANDS IN SOUTHERN SPAIN (ESTRUCTURA Y PRODUCCION DE ALCORNOCALES (*QUERCUS SUBER* L.) EN EL SUR DE ESPAÑA)

Gregorio Montero González and Alfonso San Miguel Ayanz
Coordinador de Area and Investigador Principal
Departamento de Sistemas Forestales (CIT - INIA)
Apdo. 8111 28080 Madrid Spain

FDC: 568.535: 624.1/.3: 176.1 *Quercus suber* L.

The influence of stand structure and density on stand variables determining final cork yield quantity and quality is studied. Special emphasis is given to the following variables:

- Average cork yield quality
- Cork yield per hectare
- Cork yield per square meter of bark stripped area
- Cork yield per diameter class
- Average bark stripping height
- Bark stripping area per hectare
- Bark stripping area per diameter class

The study of these variables and their evolution with different densities and diameter compositions allow for the determination of optimum structure and density in relation to cork yield, and help in choosing the best silvicultural treatments and management systems for cork oak stands.

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Post-cut Nitrogen Mineralization Patterns in Alaskan White Spruce Forest Soils

Dr. Andrew M. Gordon
Assistant Professor
Department of Environmental Biology
University of Guelph
Guelph, Ontario, N1G 2W1 CANADA

FDC: 114.61: 32/33: 174.7 Picea glauca Voss

The effects of commercial timber harvesting upon nitrogen transformations were evaluated for the forest floor and mineral soil of mature white spruce (Picea glauca (Moench.) Voss) forest sites in interior Alaska. Nitrogen cycling was very tight in the mature white spruce forest and typical of a steady-state system. Buried-bag field estimates of ammonification for the forest floor (2.48 g m^{-2} y^{-1}) and the mineral soil (0.48 g m^{-2} y^{-1}) fit well into a schematic cycle developed around other estimates of N-pools and fluxes derived from the literature. This was also true of nitrification rates which were very low in both horizons. In the cleared areas, ammonification rates in the forest floor varied from 0.11 to 3.59 g m^{-2} y^{-1} and in the mineral horizon from 0.42 to 0.54 g m^{-2} y^{-1}, depending upon time since harvesting. NItrification rates varied from 1.49 to 3.01 g m^{-2} y^{-1} in the forest floor and from 0.24 to 0.27 g m^{-2} y^{-1} in the mineral soil. After harvesting, nitrogen mineralization processes appeared to be controlled more by abiotic than biotic factors. Whole-tree, but not conventional, harvesting may be detrimental to these sites on shortened rotations (<100 years).

Post-Harvesting Silvicultural Techniques to Enhance the Red Oak Component of Hardwood Forests

Dr. Andrew M. Gordon
Assistant Professor
Department of Environmental Biology
University of Guelph
Guelph, Ontario, N1G 2W1 CANADA

FDC: 181.65: 235.1: 176.1 Quercus rubra L.

Northern red oak (Quercus rubra L.) is commonly found growing on sandy loams in central Ontario on shallow to bedrock ridgetops as a minor component of low-quality sugar maple (Acer saccharum Marsh.) stands. This study compares the outplanting performance of both 1+0 and 1+1 red oak stock underplanted beneath the residual stand following a first-removal shelterwood cut. Competition control measures also tested were prescribed burning after planting and herbicide application around individual trees.

Seedlings subjected to burning responded with increased height growth over those from the control and herbicide treatments which generally behave similarly. This was true for both 1+0 and 1+1 stock, although the increased height growth appeared to be a temporary phenomenon only. For example, 1987 shoot growth for 1+0 seedlings from the burned area exceeded that of the control seedlings by 8 cm, shoot growth was equivalent between burned and control seedlings, regardless of stock type.

These preliminary results indicate that light burning can initially stimulate height growth, but if not repeated, may be of little use in the longer term. Larger stock responds better to burning than smaller stock.

Temperate Agroforestry Research in Southern Ontario, Canada

Dr. Andrew M. Gordon and Mr. Peter A. Williams
Assistant Professor; Research Associate

FDC: 26: (212)--01

In a North American context, agroforestry involves the incorporation of forest tree species into farming operations. The intercropping of farm and forest crops, silvipasture, and riparian reforestation are more recent additions to the more traditional aspects of agroforestry such as farm woodlot management, maple syrup and Christmas tree production, and windrows and shelterbelt management. Agroforestry is seen as a partial answer to concerns brought on by widespread soil degradation, faltering farm economies, water pollution, lack of landscape diversity, dwindling wildlife habitat and increasing general interest in conservation or land stewardship. These concerns are immediate in southern Ontario where intensive agricultural land uses are often in conflict with urban demands for real estate on one hand and conservation practices on the other. Studies into methods and effects of the reforestation of degraded agricultural streams have been ongoing at the University of Guelph since 1984. However, the greatest efforts have been expended in the intercropping of valuable hardwoods with agricultural crops.

INTEGRATED PLANNING CONCEPTS FOR PROTECTION FOREST REGENERATION AND UNGULTE GAME MANAGEMENT

Hartmut Gossow

Department of Forestry
University of Land Use Sciences
Vienna, Austria

SUMMARY

FDC: 627.1: 23: 156.2: 149.6: (23): (4)

The forst-die back development of alpine protection forests and the frequent over-aging of steep slope forests has increased the importance of natural forest regeneration (where necerssary, also of artificial afforestation). Game ungulate browse and peeling (locally also by hares, microtines, and not at least vegetation impacts by "variante" skiing activities through forsted areas) is most often detrimental to such regrowth - the more in connection with dieback-impacts. Forestry planning is usually performed estate-wise or for farmland or municipality forests also more regionally. Game management (predominantly bag) planning also concerns real-estates or even smaller hunting territories (down till 115 ha). For seasonally migrating or altitudinally more mobile game species like red deer (Cervus elaphus) and chamois (R. rupicapra), a more regional management planning and effort integration should be desirable as well as a(n also) more habitat management-oriented forestry planning and practice, including not at least also a more cautious winter/spring tourism. But legislative prerequisites are quite often insufficient for adequate implementation of such integrative management strategies. Only most recently, and still as single cases, hunting and/or forest law adaptation seems more promising. A IUFRO workshop in Salzburg, in 1988, tried for a first time to bring together experts within this new field (for Middle Europe) and to discuss experiences, problems and outlooks - what is reviewed in this paper to some extent. Of special importance appears the acceptance by **foresters** that man-made and man-used forests are often predisposed too much to game damages, and by **hunters** that managment measures (like feeding, hunting impacts and the like) must be considered and implemented with regard to regional game habitat demands more than to local hunters' interests and the single hunting territory ("Revier") only, and by winter **tourists** that theire activities mean too often strong harassment for overwintering game wildlife.

NATIVE FOREST MANAGEMENT
SURPRISING YIELD - A CONCRETE POSSIBILITY

Dr. Hans Grosse
Head of the Regional Division
Instituto Forestal, Concepción, Chile

FDC: 228.8: 624: (83)

Since the days of the conquest, chilean native forests have been the mainstay of timber production. During the last decades, massive forest plantings have been carried out to satisfy the future demand for forest products. They are mainly based on the exotic species Pinus radiata and some species of the genus of Eucalyptus, due to their rapid growth and to the fact that their management and usage techniques were known. For a long time, native forests were excluded from this process since their real potencial and yield and their wide range of usage were unknown. The presence of native ressources on more than 85% of the area considered as covered by productive forests and an increasing need to incorporate them into the country's economic process have led during the last years to the necessity of making studies to get to know their forest techniques and yields.

Many of these studies are based on young developing stands which allow a profitable short-term forest orientation. They are usually forests of second growth which originated after the burning and exploitation of large areas, mainly made up of species of the genus of Nothofagus. Stands of this kind submitted to forest management exceed an average diametrical growth of 1 cm, which shows in yearly volume increases of 15 to 25 m^3. Old forests, empoverished by consecutive exploitations will have to be transformed into production units through natural or artificial regeneration. Their incorporation as productive units of constant yield will be possible in the medium term.

Generally, forest management concepts for mixed forests have to be applied considering species of more and less tolerance to shadow on the same area unit.

The price increase on the world market for broadleaved timber becomes an incentive to incorporate the masses of native forests as soon as posible into the productive forest process by means of a rational management.

Therefore, two of the most important challenges for the chilean forest branch during the coming decades are the application of forest management concepts to its native woods, maintaining the balance between areas covered by native and by exotic species.

PROPERTIES OF LESSER KNOWN SPECIES OF INDONESIAN RATTAN

Sutjipto A. Hadikusumo

Faculty of Forestry
Gadjah Mada University
Yogyakarta, Indonesia

SUMMARY

FDC: 175.2: 812.7

In order to conserve rattan supply, properties of lesser known species are observed. The properties observed are bending strength, tensile strength, compression strength parallel to grain and bending characteristic without fracture on small rattan. Rattan having the same properties or higher than the commercial ones are considered desirable and are suggested to conserve.

Keywords: Rattan, properties

CHANGES IN STAND HYDROLOGY AND CLIMATE OF YOUNG NORWAY SPRUCE DUE TO PRECOMMERCIAL THINNING.

H. Hager
Assistant Professor, Institute of Forest Ecology
Universität für Bodenkultur, Wien, Austria.

FDC: 116.28: 111.88: 241: 174.7 Picea abies Karst.

Precommercial thinning is an early and schematic thinning treatment, which is used throughout Europe mostly in sapling stage conifer stands. It results usually in higher stand vigor and value, the individual tree reacts with improved stability and better growth. Necessarily many ecological or growth factors are changed by precommercial thinning.

A precommercial thinning experiment with three intensities was set up in 14-year old Norway spruce to study the effects upon stand hydrology and climate. The experimental site was on a nearly level mountain plateau, 960m a.s.l., in Lower Austria, 80km west from Vienna. Original stocking density, which was kept in one control plot, was 5760 stems ha^{-1}, while three plots were thinned in winter 1978/79 to 3947, 3088 and 2165 stems ha^{-1}. For the measurement of water input during the vegetation periods of 1981 to 1983 throughfall and precipitation collectors were used in the plots and in the open. Soil water potential was measured with an array of tensiometers at different depth. Each plot had in the center a 12m high meteorologic tower, which was outfitted with sensors to measure soil and air temperature, humidity and windspeed profiles and global and net radiation at one height. During the period 1981-83 all meteorologic data were logged for selected days and weather conditions as 15-minute averages with a computer controlled data acquisition system. No replicate treatments were installed due to limited funding.

Hydrologic reaction to thinning was a significant decrease in stand interception loss. During the vegetation period of 1981 the heaviest thinned plot had a plus of 130mm in effective precipitation on the forest floor compared to the control plot. But differences were rapidly decreasing, especially for the moderate thinnings, through rapid replenishing of leaf area. In 1983 only the most intense thinning had still, with a difference of 80mm, significantly less interception than the control. With increasing thinning intensities soil water depletion, as measured with tensiometers, was advancing more slowly and was reaching to shallower depth than in the untreated control plot. Soil water recharge after heavy precipitation was advancing faster and reaching to greater depth the more intensive the thinning was. Despite of decreasing differences in water input with time after thinning, soil water potentials showed even five years after treatment marked differences between thinning intensities, which could be attributed do differing water consumption.

Thinning affected stand climate and energy balance. Soils were warming and cooling faster the heavier the thinning was; i.e. soil heat flux had a larger amplitude. For clear weather air temperatures in the upper canopy were during the day warmer and during the night colder in the unthinned control than at the same height in the thinned plots. For overcast weather no such trend could be observed. Vapor pressure at the same canopy level was highly dependent upon soil water status of the concerned plots. Early in the season with ample water supply vapor pressure was higher above the control plot than above the thinned plots, with limiting soil water the situation was reversed. This was confirmed by computation of sensible and latent heatfluxes for heavily thinned and unthinned plots for selected days. With thinning wind speeds in the canopy layer increased, and resulted in increased aerodynamic roughness and decreased zero plane displacement of the stands. In consequence a higher deposition velocity for air pollutants may be expected. So the many positive changes of the physical environment in sapling stands after precommercial thinning may be offset. (Research was supported under FWF-Proj. 3466 & 5089.)

MOVEMENT OF FERTILIZER ELEMENTS IN FOREST SOIL SOLUTION

K. Haibara and Y. Aiba
Associate professor and professor
Department of Forestry, Tokyo University
of Agric. and Technol., Fuchu, Tokyo, Japan

FDC: 237.4: 114.52: 181.34

It is important for maintenance of soil productivity to clarify the mechanism of nutrient circulation in a forest ecosystem. The movement of nutrients in soil is an important part of the circulation of nutrients in an ecosystem. Nutrients in the soil solution control nutrient movement in the soil by adsorption-exchange and dissolution-deposition of chemical compounds and elements. Especially, it is important for site porductivity and forest fertilization to clarify the mechanism of nutrient movement brought about by precipitation in soils that have high levels of microbe activity. Two factors that are important for studying the movement of nutrients in a forest soil are the concentration of nutrients in the soil solution (intensity) and the capacity of supply to the soil solution from the soil (capacity). Until now, the movement of nutrients in a forest soil has been treated as a black box.

We studied the movement of fertilizer elements in soil solution by using porus ceramic cups (handpump attached to a buried ceramic cup), ion exchange resin (IER) bags, a centrifuge, and stream discharge.

The change of Ca^{2+} and Mg^{2+} concentration in the soil solution had the same trend as the NO_3^--N concentration. Ca^{2+} and Mg^{2+} were released in equivalent amounts into solution from the exchangeable Ca^{2+} and Mg^{2+} in the soil (capacity factor) with the increase of NO_3^--N in the soil solution (intensity factor) due to the fertilization. The change in concentration of K^+ was different than that of the NO_3^--N, Ca^{2+}, and Mg^{2+}. Na^+, K^+, and Mg^{2+} concentration in stream discharge were higher than in the soil solution (collected by the ceramic cups). Stream discharge and soil solution concentrations of NO_3^--N and Ca^{2+} were the same. The amounts of Ca^{2+}, Mg^{2+}, K^+, and Inorg-N adsorbed by the IER from a surface horizon (ex. 5 cm depth) were several times greater than that adsorbed at a lower horizon. At the lower horizon (ex. 80 cm depth), the amounts of fertilizer elements adsorbed by the IER per unit area were nearly equal to those found in the stream discharge. The amounts of NO_3^--N and Ca^{2+} found in the soil solution (up to pF 4.2) increased with fertilization, but K^+ and Mg^{2+} did not increase.

THE EFFECTS OF SITE AND ITS INTERACTIONS WITH FERTILIZING ON THE FOLIAR NUTRIENT CONTENT OF *EUCALYPTUS GRANDIS*

M A Herbert

Senior Silviculturist
Institute for Commercial Forestry Research
University of Natal
Pietermaritzburg, South Africa

FDC: 546: 114.521.5: 237.4: 176.1 Eucalyptus grandis

Although foliar analysis is commonly used to diagnose the nutritional status of trees and their ability to respond to fertilizing, it is also a measure of site type and quality. The availability of nutrients in the soil varies with climatic and biotic as well as edaphic factors, while uptake by the plant depends on more than the nutrient status of the soil. This paper examines the foliar nutrient concentrations and ratios of *Eucalyptus grandis* as expressions of climatic and edaphic factors for a wide range of sites, in order to characterise sites and their suitability for afforestation. Foliar responses to fertilizing are similarly investigated. Important soil parameters include soil depth, organic carbon content, extractable P, exchangable Ca, Mg and K and exchangable acidity. Mean annual precipitation and air temperature are also related to the foliar nutrient content. Owing to the absence of acute deficiencies, foliar ratios are generally more suitable than single elemental concentrations in discerning between sites and describing the effects of fertilizing. There is a need to stratify sites according to climatic zones, in order to derive foliar norms for the optimum growth of *E.grandis*.

Additional keywords : Mean annual precipitation, temperature, soil organic matter, foliar norms.

MORPHOLOGICAL STUDY ON THE PREDICTION OF THE SITE OF THE SURFACE SLIDES

H. Hiura
Doctor, Research Associate
Department of Rorestry, Fac. of Agriculture
Kyoto Prefectural Univ., Kyoto, Japan

FDC: 116: 58: 114.1

Sediment yield produced by frequent surface slides on the mountain slopes of granitic rocks become as dangerous as those produced by gigantic landslides or large scale slope failures, because of the high frequency of occurrence in a basin in spite of the dimension.

After the investigation of the yearly fluctuation of the number of occurrences by the interpretation of aerial photographs, the author has recognized that the fluctuation of the number of occurrence and the transition of the number in the future could be estimated by the Weibull Distribution Function : the values of three parameters, included in this function, fluctuate with the transition of the slide numbers.

As investigated in the foregoing investigations of the author, the number of surface slides tends to increase if no proper couter measures are planned. In this paper, the methodologies of distributing the number of the future slides, simulated using the above mentioned distribution function, and drawing them on the topographical maps to make "Hazard Map" are discussed. To predict the exact site of occurrence of the surface slides is eagerly necessitated for the plan of the regression of the sediment disasters. For this purpose, morphological studies were employed.

The mapping of hazardous zones could be successfully done by the investigation of the streamline distribution map, relief map, summit level map and using additively the results of the in situ measurement and the investigation of the structure of the surface layer of the mountain slopes.

Nutrient Management of Forest under Stress for Improved Health and Increased Productivity

Reinhard F. Huettl[1] and Ian Hunter[2]

[1]Forestry Department
Kali und Salz AG, Kassel, West Germany

[2]Forest Research Institute
Forestry Ministry, Rotorua, New Zealand

SUMMARY

FDC: 181.4: 424.7: 237.4: 62

A discussion concerning major results of two IUFRO symposia held in October 1987 in Canberra, Australia, and in September 1989 in Freiburg, W. Germany, respectively on the general topic of management of nutrition in forest under stress for improved health and increased productivity is presented.

The key to nutritional management of forest under stress is knowledge: knowledge of the biological processes that are affected by stress; and profound knowledge of the land-base in all its variability such that the impact of stress can be quantified. By stressor we mean any influence which takes the forest close to or across the limits of its biological tolerance. By management we mean any activity likely to reduce the stress. Foresters have always managed forest to reduce various forms of stress. Thinning is a form of reducing the competitive stress between individuals in the forest. Forest hygiene was aimed at preventing a destructive build-up of pathogens. However, management for stress is of new and pressing concern because as a result of anthropogenic activity new stressors have appeared.

At the Canberra conference contributors concentrated on exposing new knowledge that was relevant to the theme "Interactions of moisture and nutrients" and in identifying gaps in knowledge. The Freiburg symposium illustrated that "new type" of forest damages are frequently associated with nutritional disturbances. These specific declines represent an international problem, occur over wide areas but are related to specific site and stand characteristics. Particularly the soil chemical condition is a major predisposing factor. Even-though the recent forest damages in Europe and North America seem at least in part related to the impact of air pollution through direct and/or soil mediated mechanisms, Mg deficiency - the most dominating phenomenon of these declines - has more recently also been found in areas free of these adverse influences, e. g. in Pinus radiata of northern New Zealand. Regarded as another truly new phenomenon are nutrient disturbances in various forest tree species induced by high atmospheric N deposition rates as observed e. g. in The Netherlands.

In general, it has been strongly re-inforced that fertilization and liming can help to mitigate or even remove specific stress symptoms and improve vigor and growth. However, these practices have to be applied properly depending on site and stand specific requirements. To avoid potential environmental hazards fertilization and liming practices should always be based on the results of site and stand analyses. Furthermore, through older fertilization trials it could be demonstrated that trees and stands well supplied with nutrients are more resistant to any type of stress including air pollution effects.

DESTRUCTION OF FOREST AND DEVELOPMENT OF MUDFLOW IN CHINA

Li Jian and Rui Chengdu

Institute of Mountain Disaster and Environment
Academia Sinica

FDC: 914: 116.2/.3

It is well known that China with only 12% of forest cover, is one of the countries with the lowest forest resource. At present the forest area of China is rapidly decreasing and by the year 2000 the exploitable forest will be exhausted. Every year discharges of soil and water reach losses of about 5 billion tons for the whole country; about half of it comes from the sole Yangze River drainage. Nature disasters as mudflow, landslides etc. are continuously taking place and are steadily increasing. According to statistics, mudflows exist in 24 provinces, cities and self-government districts in China and there are more than 10 000 mudflow gullies, especially in Southwest China.

Besides the natural, physical factors (geology, geomorphology, climate etc.) responsible for soil and water losses through mudflows, an important reason for the observed increase of the disasters is the disturbance of the ecological environment essentially due to the important deforestation (large scale cuts for wood production) during the last 30 years. In the Sichuan province the forest cover changed from 19% in the early 1950s to 13.3% in 1980. Owing to the decrease of forest, a catastrophic flood happened in Sichuan in 1981. In 91 counties out of the 193 counties of the province, the forest cover is less than 10% and in 10 counties it is less than 1%. More than 2000 mudflow gullies are spread over the province. It is especially worthwhile to mention that the percentage of forest cover of Huaying Sichuan decreased from 68.6% before 1958 to 7.8% by 1979 and is still decreasing. That is the result of the local people's unreasonably short period economic action causing severe damage to the forest. This resulted in heavy soil and water losses in this area and an increase of deposits in Huaying River at an average speed of 10 cm per year, so that a thrilling disaster of mudflow happened in October 1989 where about 300 people lost their life and Huaying city suffered heavy economic damage.

The Xiaojiang River basin in northeastern Yunnan can be considered as a nature museum of mudflow. It was recorded that 300 years ago the Xiaojiang River basin had green hills with dense forests and clean water. With the growing human disturbance i.e. forest-cutting, charcoal-making, bronze-smelting etc. the mountainous environment has been destroyed. The forest cover in Dongchuan city in the middle of the Xiaojiang River was about 30% in 1950 and decreased to 12.84% by 1984. In some regions all the forest disappeared and a desert scene is left with naked hills and mountains, broken slopes and mudflouws rolling in gullies which appeared over the whole basin. Based on survey, there are now more than 150 relatively large mudflow gullies in the Xiaojiang River basin, far exceeding the 38 existing in the 1950's. Others provinces of China have a similar situation. The erosion of slopes is accelerated and mudflow disasters have also continuously increased. In a word, we have completely reason to believe that many environmental disasters are caused by man's unsuitable economic activities. Obviously, the main reason for the gradually diminishing protection function of the forest is mainly due to bad management and the destruction of the forest.

THE INTEGRATED STUDIES ON ECOSYSTEM OF PINUS KORAIENSIS PLANTATION FORESTS IN NORTHEAST CHINA

Liu Jianwei

Botanical Institute
Northeast Forestry University
HARBIN, China

FDC: 181.2/.3: 238: 174.7 Pinus koraiensis Sieb. et Zucc.

Pinus koraiensis is not only a famous tree for wood, but also a dominant species in the vegetation of northeastern China. For its valuable wood, *Pinus koraiensis* plantations are under management and silvicultural treatment since 1950. In the natural *Pinus koraiensis*-deciduous broadleaved forests, studies concerning the biological nutrient cycling, the biological productivity and the decomposition of litter have been executed.

The studies of the ecosystem of *Pinus koraiensis* plantations were made in a 27-years old *Pinus koraiensis* plantation at the Experimental Station of the Northeast Forestry University in the Lao Shan Mountain.

The investigations concerned two fundamental aspects : nutrient cycling and energy fluxes. At first, it has been tested the biomass, annual net production, annual and current annual increment as well as monthly litter fall and decomposition of litter in order to understand the laws of fixing, distributing, converting, decomposing and returning of the nutrients in the ecosystem.

Concerning the energy flux, the input, the output, the fixing and the loosing are respectively mesured by radiative apparatus and bomb calorimeter. The daily and monthly energy uptake of standard sample trees have been estimated by Beckman CO_2 Infrared Analyzer through the daily and monthly process of photosynthesis. Moreover, the processes of the radiation balance, the water balance and the heat balance as well as the characteristics of the effective nutrient cycling between them have also been studied.

Besides, the stability and adaptability, the static and dynamic models of interaction between radiation, water and nutrients (also considering productivity and biomass) have been discussed.

With these studies, the ecological functions and dynamics of the *Pinus koraiensis* plantation ecosystem have been pointed out and the productivity of the nutrient and the energy budget have been determined. It is important to treat and to manage the forests of *Pinus koraiensis*, especially the fast growing plantations.

RELEASE CUTTING AND RATIONAL STRUCTURE OF KOREAN PINE AND BROADLEAVED TREE MIXED PLANTATION

Li Junqing
Department of Forestry, Northeast
Forestry University, Harbin 150040, China

FDC: 243: 232: 174.7 Pinus koraiensis Sieb. et Zucc.

Korean Pine (Pinus Koraiensis) Forest are the widely spread zonal vegetation in Lesser Xingan Mountains and east mountain areas of Northeastern China. Owing to the unrational exploitation and backward in technology and managemcnt, the forests, especially the virgin forests,grow slowly and regenerate poorly . Both areas and stockings have been reducing in a high speed since 1950s .In order to reserve and develop the forests, large areas of Korean Pine sedlings have been planted in the eastern part of Northern China. But most of them are not growing as well as expected, herein lies a unsolved problem is that what structure should be more productive and what kind of tending method should be taken during the young growth process. This paper is intended to demonstrate what kind of forest stucture would be more productive, more efficency in light energy utilization and more advantageous in nutrient staus, so as to provide some information for the ways of silvicnlture and management.

A mixed coniferous and deciduous tree forest was formed on an homogeneous plot by planting Korean Pines and natural regeneration of some broadleaved trees in 1967. Eight yeas later, the colonized broadleaved trees became higher than those pines. Release cutting removed all and 50% broadleaved trees over pines, respectively, and therefore two stands in different structure were formed. Surveying in 1987 found that the half-releasing stand was low in density but with two story distribution of trees , while the all-releasing stand was high in density with mono-story distriotion of trees. Furthermore, the half-releasing stand, comparing with the all-releasing stand, was characterized by:

(1) low survival rate of pines and poor natural regeneration of the broadleaved trees;
(2) growth fast and 1.5 times of standing stockings of the all-releasing stand;
(3) 1.3 times of leaf area index, 0.8 times of leaf area density and 1.3 times of productivity of the all-releasing stand;
(4) high concentration and fast accumulation of inorganic elements in tree bodies;
(5) $100.3 \times 10^7 J/m^2$ season of radiation absorption and 0.03% light energy utilization rate more than the all-releasing stand .

Finally it has been demonstrated the stand story structure, not density , affects the above testing results, so the conclusion is that the multistory structure of the half-releasing stand is more rational than the all-releasing stand.

"ANALYSIS OF THE BIOPHYSICAL AND SOCIOECONOMIC FACTORS RELATED TO INDIGENOUS SYSTEMS IN THE MIDHILLS OF NEPAL."
Karki, Jay Bahadur Singh. University of the Philippines at Los Baños. September 1989.

Major Professor: Dr. Domingo M. Ramirez

FDC: 91: 26: (541.35)

The study analyzed biophysical and socioeconomic aspects of indigenous agroforestry systems in the midhills of Nepal; and focused on land-use patterns and people's perceptions of, and attitude towards, the systems. Primary data were obtained through interview and observation.

The predominant land-use systems in the area included three traditional, locally developed agroforestry systems. These were agrisilvicultural, silvi pastoral and agrisilvipastoral systems. Subsystems were: multipurpose trees on farmland, Shelter for plantation crops, windbreak and homestead garden, fodder orchard, tree grazing system and protein bank; and grazing or browsing system.

Associated with the agroforestry systems were four farming systems i.e., home garden only; home garden and paddy; home garden and upland; and home garden + paddy + upland. Analysis of farming systems focused on the dominant cropping pattern. Single-component, double-component and multiple-cropping systems were distinguished.

Farmers showed favorable attitudes towards locally-evolved agroforestry systems; although several expressed openness to some change. Perception was significantly related to socioeconomic characteristics (i.e., education, oncome, and farm structure). Farmers' attitudes were related to: education, occupation, income, household size, and farming system. Age, sex, caste, religion, farm size and family work force and no bearing on perception or attitude.

Recommendations based on the study were grounded on using an approach characterized by the refinement or improvement of existing land-use systems rather than radical transformations from the outside.

DEVELOPMENT OF SHORT ROTATION INTENSIVE CULTURE IN EASTERN ONTARIO, CANADA

R.K. Keane
Senior Program Technician
Ontario Ministry of Natural Resources
Brockville, Canada

FDC: 238: (713)

Short rotation intensive culture of hybrid poplar plantations has been under development in eastern Ontario, Canada since 1974 for the primary purpose of producing wood fiber for the production of pulp and paper. The development began as a result of a shortage of wood fibre for a local fine paper mill, an abundance of surplus, marginal agriculture land and the availability of a genetic resource from past research efforts.

The focus of our program in the beginning was to develop a soil survey procedure suitable for the delineation of the highly variable soils of eastern Ontario. A clone/site trial program was implemented at the same time which has enabled us to match specific clones to specific sites, to maximize potential productivity.

Silvicultural techniques have been developed through a series of trials such as block spacing and Nelder spacing trials to investigate plantation density, rotation and yield and to identify appropriate management systems; herbicide trials to investigate crop tolerance of hybrid poplar to various suitable agricultural herbicides; and planting stock trials to look at stock options for plantation establishment. The current trial program is investigating fertilization and coppice management.

A series of clone specific and general volume and biomass equations have been developed for hybrid poplar grown on 10-15 year rotation. Development in this area is continuing.

New clones for the production program are being screened for important diseases by artificial inoculation techniques and then tested for productivity and site suitability.

The production plantation program is approximately 3000 ha in size with 200-300 ha being planted annually. The first production harvest in 1989 yielded a mean annual increment of 3.2 oven dry tonnes per hectare per year.

THE POSSIBILITIES OF ACCELERATION OF TIMBER-GROWING AND UTILIZATION FOR ENERGY AND ITS DEVELOPMENT IN HUNGARY

B. Keresztesi[1], L. Halupa[2], K. Rédei[3]
[1]Research Professor, [2]Head of Department, [3]Senior Research Worker
Forest Research Institute, Budapest, Hungary

FDC: 238: (439.1)

In the past years, on behalf of the Ministry of Industry and the Ministry of Food and Agriculture, a research team investigated the quantity and utilization of the present utilizable dendromass which would be also used for energy and its development possibilities in Hungary.

This paper contains the most important statements and proposals of the report.

The mechanization of harvesting operations and wood utilization, and the use of convenient equipment could increase the present wood material, which may be also used for energy purposes, by 600,000 m^3.

In the next 10 years 150,000 - 200,000 ha new afforestation will be planned on those areas which are not utilized economically by agriculture; from this 50,000 - 70,000 ha of short rotation energy forest may be established.

Taking into consideration the site conditions, on the basis of the data of Hungarian and foreign trials, energy forests can first be established with black locust (*Robinia*) and poplar (*Populus*) species.

Under particular site conditions (flood-plain, soil saturated with native soda) different *Salix* species and *Ulmus pumila* can be cultivated with good results.

By utilizing wood material and agricultural secondary products, not currently being used, and by planting energy forests and establishing the required caloric centres, the rate of energy gained from biomass would be increased from 4.5% to 10% by the end of 1990.

GREAT POSSIBILITIES OF AN ORIGINAL DYNAMIC ADSORPTION METHOD PHYSICAL MODELLING OF MOMENTUM; HEAT AND MASS TRANSFER IN THE PRESENCE OF HIGH VEGETATION

S. Koncar-Durdevic
Professor, Faculty of Technology
and
Olga M. Stojanovic
Doctor, Institute of Agricultural Economics

Belgrade, Yugoslavia

FDC: 161.1--01

Our original dynamic adsorption method (DAM) is based on dynamic adsorption of the dye from water solution over the models of objects covered by white adsorbence. By applying DAM, the differently coloured surfaces of the object are obtained, depending on the local intensity of the mass (dye) transferred over it. Lasting colour intensity corresponds to the mass transfer intensity.

Starting from chemical engineering principles, it has been proved that there exists the analogy between mass, momentum and heat transfer in gaseous and liquid medias. By applying physical modelling on the parts of the separate plants or their groups, the three transfers may be imitated, i.e. studied. They make a part of the basic plants physical vital functions. In this way the information on superficial exchange of useful and nocuous substances from the streaming air can be obtained, as well as of heat transfer, i.e. friction when the air is streaming around them.

DAM enables better knowledge of physical effects of the environmental factors only, it enables better understanding of the complex plants phenomena followed by chemical and biological influences in environment. Some newly noticed phenomena are shown. We examined the mass transfer when the fluids were streaming on the leaf under different conditions:

- Transfer phenomena around the cylinder and
- Transfer phenomena on the crown tree models of the different types.

RESEARCGES ON NEEDLE WEIGHT OF DAMAGED NORWAY SPRUCE TREES FOR A BETTER TERRESTRIC DAMAGE ASSESSMENT

W.H. Lanz
Fachhochschule Hildesheim/Holzminden, Fachbereich Forstwirtschaft Göttingen

FDC: 539: 425.1: 425.3

For the purpose of quantifying the actual forest damage every year in the Federal Republic of Germany the condition of tree crowns are assessed by terrestric observation.This is a very subjective method and should be improves by exact measurements. Therefore in different spruce stands needle samples have been collected from 48 trees in order to determin the needle weight. This was done in four different crown sections and separated in needle age classes. Furthermore the colour, the pathologic symptoms,the "100-needle-weight", the "100-needle-length", the nutrion content of the needles, also the volume and the surface area of the crowns and the radial and hight increment has been determined.

The most important results are the following:

1. With the size of the crowns the percent of assessment error was increasing.
2. In well growing spruce stands the needle weight proportion was relatively equal in the differnet needle age classes. With increasing tree damage the weight of the elder needle age classes have been decreased. In low growing spruce stands the highest percentage of needle weight have been found in the last two age classes.
3. In well growing stands the variation of the needle weight within the separate damage classes was larger than in low growing stands.
4. In all investigates stands the largest needle weight have been found in the 2nd and 3rd crown section. The lowest needle weight were founded in the highest section(1) following by the lowest section(4).

IMPLEMENTATION OF ENERGY FORESTRY ON PRIVATE FARM LAND IN SWEDEN

Stig Ledin and Lisa Sennerby-Fo[illegible]
Directors of research
Department of Ecology and Environmental Research

and

Håkan Johansson
National advicer
Research and Information Center

Swedish University of Agricultural Sciences
Uppsala, Sweden

FDC: 238: 923.4: (485)

Salix species are used for energy forestry in Sweden. Cuttings are planted in the spring on prepared farmland. The stands are intensively managed, including weeding during the establishment phaze and fertilization during the production phaze. Harvest is done every 3-4 years and new shoots sprouts form the stump after each harvest.

Renewable, environmentally acceptable energy sources are of high interest today and will be even more so in the future. In Sweden, political decisions have been taken that outlet of CO_2 to the atmosphere must not increase within the country. At the same time there is an over production of grain in Sweden as in many western countries. This circumstance has led to a considerable interest for alternative crops, e.g. energy forest.

Today there is about 1.000 ha Salix plantations in Sweden. The farmers organizations are supporting projects with the aim to develop energy forest into a farm crop. A total area of 10.000 ha will be planted up til the year 1993. In a time perspective of 15 - 20 years, cultivation of Salix plantations could be done on about 300.000 hectares. A continuous development of the production technique, mainly harvesting and handling of the wood will lead to a successive improvement of the economy of energy forestry.

Assessing the Fire Hazard of Structures in the Wildland/Urban Interface

by

Susan L. LeVan, Project Leader
Fire Safety of Wood Products
U.S. Forest Service
Forest Products Laboratory
Madison, Wisconsin

SUMMARY

FDC: 431.2

The hazard to structures in the wildland/urban interface (WUI) has been increasing as people move from the cities into rural areas. This movement h[illegible] increased the likelihood of wildland fires occasionally threatening these structures. Forest fire fighters now have to defend these structures from wildfires, which increases firefighting costs, may result in a much larger wildfire with loss of natural resources, and may result in an even greater loss of structures. To reduce the risk to structures in the WUI, quantitative systems are needed to evaluate the fire hazard of structures in these settings. This paper describes an evaluation methodology that could be used to develop a fire hazard assessment procedure that provides a quantitative measure of the relative fire hazard of structures within the WUI. The procedure presented uses input from experts to evaluate the fire risk contributed by the structure, the wildland fuel, and the topography. A feasibility study indicated that such a procedure may have some potential problems. Problems and possible alternatives are presented.

COMPARATIVE RESPONSES OF *PICEA MARIANA* AND *PINUS BANKSIANA* SEEDLINGS TO INTERSPECIFIC COMPETITION

G.B. MacDonald
Research Scientist
Ontario Forest Research Institute
Sault Ste. Marie, Ontario, Canada

FDC: 181.41: 174.7 Picea mariana B.S.P.: 174.7 Pinus banksiana Lamb.

Indices of interspecific competition were formulated and tested for their ability to explain variation in diameter increment of black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) seedlings. The optimum index was calculated as the amount of competing canopy on hemispherical fisheye photographs, relative to the seedling leaf area. An alternate index which performed well but required no elaborate equipment was the sum of the relative competing stem volumes of the largest competitor in each quadrant surrounding the seedling. The relationship between growth and competition was adequately modelled with a modified negative exponential function.

Growth comparisons were made using functional growth analysis, with species and stock types as treatments. The conventional time axis was replaced by a competition axis. Graphical analyses revealed that jack pine and bare root stock of both species maintained large growth advantages despite greater sensitivities to competition, compared to black spruce and container stock, respectively. Thus, jack pine or bare root stock of black spruce would outperform the alternatives if tending were delayed, but competition should be removed before becoming heavy in order to capture the maximum growth potential of the species or stock type.

The rate of growth decline in response to competition was consistently greatest at the lowest competition levels, indicating there can be no beneficial effect on growth of a light cover of non-crop vegetation. Sharp levelling of growth responses suggested that greater percent increases in plantation growth could be achieved by removing low levels of competition than by reducing the intensity of competition from high to low.

Allometric analyses indicated that black spruce had a greater morphological plasticity than jack pine. At high competition levels black spruce allocated more biomass to branches and foliage, at the expense of roots, while jack pine demonstrated no such adjustment in allocation pattern. However, the strategy of stress-avoidance through sustained high growth rates in jack pine makes this species preferable to black spruce, from a volume production standpoint.

SEDIMENT DYNAMICS OF A HIGH GRADIENT STREAM IN THE OI RIVER BASIN OF JAPAN

H. Maita
Assistant Professor
Institute of Agricultural and Forest Engineering
University of Tsukuba. Ibaraki. Japan

FDC: 116.3: (52)

Numerous researches for sediment control works in mountainous areas have been done. However. the understanding of discontinuity as well as history of sediment transport is not enough. This research deals with a series of changes of river-bed morphology by 9 floods in a high gradient gravel-bed stream.

The study reach is the upper part of the Higashigouchi river which is a small tributary of the Oi river. This area is located in the high up-lifting zone of Japanese Southern Alps. where the volume of specific sediment yield is as many as 2000 to 6000(m^3/km^2/year). Main lithology of this region is cretaceous sedimentary rock. This study reach is a high gradient gravel-bed stream(1/8 to 1/15 in slope) and extends 1 km where the stream coming through the V-shaped narrow valley first meets a wide(40-130m) floor bottom.

The 9 changes of river-bed morphology by floods were confirmed from 1979 to 1985. and for each change. profile leveling and cross sectioning(to 22 lines) were carried out in the reach. A threshold rainfall for the occurrence of the change of river-bed morphology in the reach is a maximam hourly rainfall of about 30mm or a daily rainfall of about 150mm. In 1982, the basin got an intense rainfall amounted to about 900mm(about 30-year recurrence interval), and the sediments exceeded 150.000m^3 in volume deposited on the river-bed in the reach. Since then, rapid erosion of the river-bed ensued and the river-bed has been recovering its former profile. and also the channel has been nearly regaining its former shape and form.

These changes were analyzed quantitatively using the volume of river-bed variation which was culculated by the end area formula using the cross sectional shapes before and after the change of river-bed morphology. According to the analyzing. the volume of river-bed variation did not correspond to the magnitude of flow discharge, but in the erosional process after the large deposition of 1982, the specific volume(S) of river-bed variation which was arranged in flood occurrence order(t) decreased exponentially with its order. Here. the specific volume of river-bed variation is that the volume of river-bed variation is divided by peak flow discharge. This relation is expressed by the equation of $S(t)=-\alpha\exp(-\beta t)$, where t is expressed as 1.2,···. In the study reach, α is 3.3. β is 0.8. The value of β shows how river-bed width to give the infuence on the volume of river-bed variation. The wider river-bed width gets, the smaller the value of β gets.

In conclusion, the emphasizing points are as follows:

1) Deposition or erosion on the river-bed depends mostly on the sediment supply. not on the magnitude of flow discharge.
2) Wide parts of river-bed of a valley are depositional space where excess sediments from the upper stream doposit temporarily, in the erosional process after that. the doposited sediments are exponentially subdivided into small amount of sediments, which run off to the down stream. Therefore, wide parts of river-bed are also the retarding space for sediment transport.

RECHERCHES SUR LA DYNAMIQUE DES PEUPLEMENTS ARBORES EN VUE DE DEFINIR UNE SYLVICULTURE ASSURANT LA CONSERVATION ET LA PRODUCTION DURABLES DE L'ECOSYSTEME FORESTIER TROPICAL HUMIDE

H. F. MAITRE

Programme Aménagement Forestier du Centre Technique Forestier Tropical Département du CIRAD France

FDC: 181.5/.6: 624: (213)

Le programme de recherches du CTFT sur la dynamique de la forêt tropicale dense humide a pris une réelle envergure depuis un peu plus de dix ans grâce à une approche scientifique plus concrète bénéficiant de moyens financiers à la mesure des enjeux et des nouvelles possibilités de calcul offertes par l'informatique. Ce programme s'appui sur un réseau de dispositifs expérimentaux matérialisés en Afrique (Côte d'Ivoire, Centrafrique, Gabon), en Amazonie (Brésil, Guyane française) et en Océanie (Nouvelle Calédonie) ou en cours de mise en place (Indonésie).

Outre la cohérence de conception et d'implantation des essais et des traitements, ces dispositifs ont pour dénominateur commun d'étudier la réaction de la forêt en fonction de deux interventions : l'exploitation forestière pour le bois d'oeuvre et les éclaircies d'amélioration des peuplements.

Les premières séries de données, issues des essais les plus anciens, ont permis de fournir des renseignements précieux sur la croissance en diamètre, sur la régénération ou sur le comportement de nombreuses espèces de valeur et d'apporter ainsi les éléments nécessaires pour démarrer des opérations démonstratives d'aménagement pour une production durable de bois d'oeuvre : atout majeur pour la protection des écosystèmes forestiers.

Actuellement, l'action de recherche entame une seconde phase : il s'agit non seulement d'affiner la validité des résultats dendrométriques quantifiables en mettant à profit le recul dans le temps, mais surtout de concentrer les efforts et les moyens pour fournir des notions explicatives ; et ceci :

. par une analyse poussée des facteurs régissant la croissance des arbres (phénomènes de concurrence) et la régénération (d'une approche très complexe),
. et par un effort important de suivi des divers types de mortalité (naturelle, induite ...) dont la compréhension et l'estimation quantifiée, s'avèrent indispensables pour atteindre un niveau satisfaisant de connaissances sur la dynamique des peuplements et pour permettre, un jour, de proposer des plans d'aménagement consolidés par des prévisions fiables de production.

MULTIPLE PURPOSE SPECIES AND FUELWOOD PLANTATION SYSTEMS IN TROPICAL CHINA

Cai Mantang
Research Institute of Tropical Forestry, Chinese Academy of Forestry
Longdong, Guangzhou, China

FDC: 238: 232.11: (510)

The tropical and subtropical provinces in the south of China suffer from fuelwood shortages. This has resulted in an escalation of firewood costs, degradation of the environment through indiscriminate and illegal cutting, and increased hardship on wood gatherers - mostly women and children. To improve this situation, an internationally supported project works on the screening and selection of fuelwood species, techniques of establishment, management of plantations, and dissemination of the results to farmers.

The results of screening and selection showed that none of the native tree species suitable for fuelwood plantations could compete with the introduced, domesticated species, already planted locally. The main reason for this was probably due to the sites: the presently available sites are of an agricultural type, sometimes eroded, shallow and hard. These are different from the sites where remnant forests and trees of native species grow. The most promising domesticated species in these trials were *Eucalyptus exserta*, *E. leizhou* no. 1. and *Acacia confusa*. The most promising introduced species in elimination trials were: *E. urophylla*, *E. camaldulensis*, *E. tereticornis*, *E. maculata*, *E. grandis*, *E. pellita*, *Acacia mangium*, *A. crassicarpa*, and *A. propinqua*.

Plantation trials of pure and mixed species were established. With pure species, spacings of 1m x 2m to 1.5m x 3m seemed to be the best for 2-4 year rotation cycles. Larger spacings were required for intercroppings. Intercropping benefited the fuelwood trees in all cases, because cultivation improved the moisture regime and aeration of soils. Mixed species plantings performed very well. Demonstration plots of fuelwood plantings with local farming communes were very successful.

EVALUATION OF RISKS ASSOCIATED WITH LIQUEFACTION CAUSED BY EARTHQUAKES

Hideaki Marui* and Shinji Uemae**
* Associate Profesor
Research Institute for Hazards in Snowy area, Niigata University, Japan
** Engineer
Nippon Kaiko Co., Ltd., Tokyo, Japan

FDC: 114.11/.12: 114.3--01

A methodology for evaluating risks of liquefaction due to seismic shaking is briefly introduced. The advantages and disadvantages of the method and the problems of applying it in practice are discussed.

During past large earthquakes the liquefaction of sandy ground has been one of the main causes of damages to various types of structures such as embankments, buildings, houses, bridges, lifelines etc. In addition to the above mentioned damages, landslides and large permanent ground displacement have been caused by liquefaction over a wide area during past disastrous earthquakes. Therefore, it is urgent need to establish a rational method to evaluate the risks of liquefaction over a wide area and to illustrate hazard map which can quantitatively indicate the hazard potential on the target area for the pupose of disaster prevention planing.

At present stage some methods are available to evaluate risks of liquefaction. These methods can be classified into three main categories. The first one is based on microtopography and history of past liquefaction. The second one is based on boring data. The third one based on the laboratory tests. For the purpose to illustrate hazard map over a wide area, the first two methods are effective and the third method is too complicated.

The method used in this study belongs to the second categorie. The method is based on the Index of Liquefaction Potential which can be introduced to express the severity of liquefaction. This Index can be calculated from three factors, that is, the N-value by the standard penetration test, the mean diameter of soil particles D_{50} and the dynamic load induced in the soil element by a seismic motion. A hazard map, which expresses the liquefaction potential in urban areas of Niigata city, is illustrated by using this Index. The Niigata earthquake, which occured with a magnitude 7.5 in 1964, caused serious damage to many structures in the costal area of the Japan Sea. In particular in Niigata City, which is locatedabout 50 km from the epicenter, buldings, bridges, oil storage tanks, lifeline facilities, etc., were extensively damaged.

The estimated hazard areas indicated in the above mentioned hazard map are compared with the investigated actual hazard areas by the 1964 Niigata earthquake. It is found that the estimated hazard areas are generally coincide with the actual hazard areas, although there remain some areas, which show no good coincidence.

In order to explain the partial noncoincidence, its preferable to introduce complementarily also the evaluation method by microtopography especially with the consideration of the origin of the soil layers in the target areas. It is recommended to use a combination of the method based on boring data and the method based on microtopography.

EROSION PROBLEMS IN BANGLADESH

Azharul H. Mazumder
Department of Forest Resources Management
College of Environmental Science & Forestry
State University of New York

FDC: 116.2: 116.6/.7: (549.3)

Bangladesh consists of Tertiary hills, Pleistocene terraces and Recent floodplains mainly of 3 great rivers. Located at a high monsoon area, it has a small land base to support a large population. It has 10 aggregated physiographic units consisting of 11 dendroecological regions (DEZ) having 3 inundation land types. Forestry is the main land use in the hills and terraces while the floodplains, excepting a large area in the estuarine floodplain, are used for agriculture.

Information on soil erosion and related aspects in the country is scanty. High seasonal rainfall expedites catastrophic soil erosion. The denuded hills are highly susceptible to rill and gully erosion mainly due to heavy exploitation of forests and shifting cultivation by tribal people. The terraces and floodplains are subjected to sheet erosion. Erosion in floodplains is compensated by regular siltation due to seasonal floods. Soil erosion is followed by land degradation. Erosion has also caused serious degradation of the watersheds. Watershed degradation has been identified as the prime cause for frequent floods which adversely affects the mainstay of the country's economy. Awareness has developed amongst the planners as well as victims. Emphasis for research on soil erosion, watershed and flood management has been given by the government. Institutional frameworks for research and regional cooperation for combating soil erosion, watershed degradation and flood problems are need.

Dept. of Forest Resources Management
College of Environmental Science & Forestry
State University of New York
Syracruse, New York 13210
U.S.A.

SITE PREPERATION TECHNIQUES FOR THE ESTABLISHMENT OF *Bombacopsis quinata* PLANTATIONS IN THE SEMI-ARID REGION OF COLOMBIA

D. L. Mengel
Assistant Director, Hardwood Research Cooperative
College of Forestry
North Carolina State University
Raleigh, North Carolina, United States

FDC: 232.322: 176.1 *Bonbacopsis quinata*: (213)

If plantations of red ceiba (*Bombacopsis quinata* (Jacq.)) and other tree species are to be successfully established on vertic soils in the semi-arid tropics, methods to increase water infiltration and improve soil moisture storage must be identified. The shrink-swell nature of vertisols severely impedes the infiltration of water when they become wet. Low infiltration rates and subsequent slow downward movement of water into the soil profile may significantly affect first-year height growth of red ceiba. Particularly, when the trees are planted during the short dry season in July-August. This research investigates the results of various site preparation techniques on early growth of red ceiba.

The study was established on a clay terrace soil in northern Colombia, in April 1989. The site, previously pasture, is in the Casablanca soil series, a Udic Chromustert soil. Four replications of a split plot design were installed. The main plots were no subsoiling, subsoiling to 40 cm, and subsoiling to 60 cm. The subplot treatments were check (no treatment), subsoiling between the tree rows, and application of organic mill waste within the tree row. The mill waste was applied as a vertical mulch within the subsoil slot or planting hole. The trees were planted on a 3 x 3 m spacing. Weed control was accomplished using a combination of chemical and mechanical methods. Rainfall was below normal in 1989.

First-year height growth was greatest in the plots with deep subsoiling and lowest in the plots receiving the mill waste. Height growth in the plots with subsoiling to 40 cm was greater than the control plots. Subsoiling to 60 cm further increased height growth. The differences were only significant at the 10% level between the control and the 60 cm depth subsoiling. Height growth was poorest on those plots receiving the mill waste. There were no significant differences between survival between the different treatments.

It appears that deeper subsoiling to 60 cm does improve first-year red ceiba height growth. This may be due to improved infiltration via the subsoiling slot. The poor performance of the trees planted with mill waste may be due to planting the trees too soon. Decomposition products from the breakdown of the organic waste material may have adversely affected early root growth. Soil measurements of moisture content and density may reveal additional factors useful in explaining these first-year results.

COPPICE ENERGY SUPPLY STRATEGIES

C P Mitchell & J B Ford-Robertson
Wood Supply Research Group
Forestry Department
Aberdeen University
Aberdeen AB9 2UD, UK

FDC: 238: 644.4: 662: 721.1

Work on energy forestry in the UK has concentrated on production scale trials with coppiced willows and poplars to determine management systems, yields and costs of production and the development of a coppice harvester. Information generated from these trials has been used to model a series of supply strategies.

The production of energy chips from short rotation coppice biomass plantations can be split into two distinct phases: 1) establishment and management or growing, and 2) harvesting and comminution. Logistics and costs of operations were recorded from the large scale trials. This information, coupled with productivity data from longer established trials, was used to develop a series of coppice fuelwood supply strategies.

These supply strategies have been modelled for three production systems (Willows planted at 10,000/ha, on a 3 year rotation with a productivity of 12 odt/ha/yr; Poplars planted at 6,666/ha on a 5 year rotation and with a productivity of 16 odt/ha/yr; Poplars planted at 2,500/ha on a 10 year rotation and with a productivity of 16 odt/ha/yr). Three costing methods are used: 1) farmer grows and harvests ie marginal (farmer) cost basis; 2) farmer grows and contractor harvests; and 3) contractor grows and harvests ie fully costed (contractor) basis. There are 4 supply options: a) harvest/bundle, transpirationally dry, chip and transport, b) harvest/bundle, chip and transport; c) harvest/bundle, transpirationally dry and transport; and d) harvest/chip and transport. Two transport distances were considered: 10 and 50 km. The Loughry coppice harvester is used for the 3 and 5 year rotation coppice crops; the 10 year poplar crop is motor-manually felled and whole tree chipped with a terrain chipper. The costs of supply are set against prices for fuel into the current domestic, long term average industrial and current industrial markets (£3.30, £2.40 and £1.50/GJ respectively).

Costs of supply over a 10 km transport distance range from £0.46 for a marginally costed operation with a 10 year rotation poplar through to £2.54/GJ for a fully costed operation with a three year rotation willow crop. All systems can supply the domestic market economically but only the marginally (farmer operated) costed systems can supply the present industrial market.

IMPACT LOAD ON THE DAM DUE TO DEBRIS FLOW

Iwao Miyoshi
Department of Forestry
Faculty of Agriculture
Kyoto University
Sakyo-ku, Kyoto 606, Japan

FDC: 116.2/.3

When a dam is struck by debris flow or mud flow, it is put under great impact load and would sometimes be destroyed. To prevent such destruction, it is important to promote basic studies about the effect of impact load on the dam due to debris flow or mud flow.

This paper describes the experimental study that has been made to estimate the effects of such impact loads on the dam.

The experiments were conducted as follow. Mixture of glass beads of 5mm in diameter and water flowed down in an open channel of 7m in length and 150mm in width. The flow was checked by the dam type load measureing device fixed in the channel, and then the amount of load was measured continuously while the sideview of the flow's behaviour was recorded by high speed video camera (200 frames per second). The measured load can be explained as static load by sediment of debris when the velocity of the debris flow is relatively low, while the load consists of dynamic pressure of the flow on high velocity. In the case of the latter, the load agree at each time with one assessed from the observed momentum variation accompanied with the deformation of flow. Then, a model has been proposed to evaluate the deformation of the flow and, in the result, the load on the dam. In this model, the initial conditions (flow depth, bulk density) are expressed in functional relationships determined from the experiments, and the load can be estimated quantitatively. The profile of the debris flow, the load on the dam, and their variation with time calculated by this model have proven to agree well with those observed or measured in experiments.

A STUDY OF WEED COMMUNITIES IN THE FOREST NURSERIES OF IRAN

Mahmoud Mohammadi

Research Associate
Research Institute of Forests & Rangelands
TEHERAN, Iran

FDC: 441: 232.320--014: (55)

At the time being, there are 84 nurseries all over the country covering about 1500 hectares. The annual yield of these nurseries is about 70,000,000 plants which are used for public walks (parks), for out-door recreation and for afforestation.

The main problem in these nurseries is the growth of weeds which cause a considerable damages and weeding amounts to more than 35% of the production costs of the produced plants. Weeds compete with young seedlings and many seedlings are injured or cut during the weeding operations. In order to elaborate suitable and economical methods of weed control in forest nurseries, it is necessary to study the weed communities.

Therefore, the flora of weeds in the nurseries in Kajal, Caspian sea coast, Gorgan, Torogh, Zirab, and Lajim, has been inventoried and studied during several years (1986-1988) from late March to early September.

In these nurseries different softwood and hardwood species are grown. The main species of weeds, covering 50% of the area, were all dominant species.

Generally, the collection and identification of weed species in the nurseries gave the following results:

- 77 species from 30 families were recognized in the nurseries.
- 24 species of weeds were common in softwood and hardwood nurseries with a density of more than 50%.
- 7 species of weeds were recognized as dominant in softwood nurseries.
- 12 species were recognized as dominant in hardwood nurseries.

RECENT PROGRESS IN A MIXED STAND OF CASTANEA SATIVA AND PSEUDOTSUGA MENZIESII IN PORTUGAL

Maria do Loreto Monteiro Maia
Silviculturist
I. N. I. A. , Bragança, Portugal

FDC: 228.2/.3: 176.1 Castenea sativa Mill.: 174.7 Pseudotsuga menziesii Franco: 653: 624.2

Castanea sativa Mill. is a native species in Portugal, known since the Miocenic period and cultivated since the Roman times. Nowadays it occurs North of the parallel 39° N., in the distribution area of Quercus robur and Quercus pyrenaica. The important role this species plays in the social ambiental, ecological, agronomical and forest fields determines that his silvicultural problems are studied.

In Portugal the productive forest is primarily composed by softwood pure stands. In Europe the actual trend goes to the establishment of mixed stands, or when possible to the gradual change of pure to mixed stands.

A study of several types of consociation of Castanea sativa x Pseudotsuga menziesii was installed in 1981. The tested treatments were: a) one row of Castanea sativa and one row of Pseudotsuga menziesii; b) one row of Castanea sativa and two rows of Pseudotsuga menziesii; c) one Castanea sativa and one Pseudotsuga menziesii, in the row; d) one Castanea sativa and two Pseudotsuga menziesii, in the row; e) one Castanea sativa and three Pseudotsuga menziesii, in the row; f) pure Pseudotsuga menziesii; g) pure Castanea sativa.

In the study plots,the diameter at 0,30 cm (1 ft), the d.b.h. and the height of plants were measured every year. The evaluation of the results wasn't made on the basis of the volumes produced, but through the weight and the commercial wood value per hectare, once the studied species presents different specific weights and prices.

The results of this study suggests that treatment a) one row of Castanea sativa and one row of Pseudotsuga menziesii, is the one who better harmonizes the weight, the commercial value and the stand management.

AN INVESTIGATION OF IRANIAN OAK (QUERCUS CASTANEIFOLIA C.A.MAY) BASED ON L. EMBERGER, S PLUVIOTHERMIC COEFFICIENT : (Q)

Ahmad MOSSADEGH

University of Teheran
College of Natural Resources
KARADJ, Iran

FDC: 176.1 Quercus castaneifolia C.A. May: (55)

Iran is an interesting country. Its geography, climate and soils are variable which means a high diversity of forests, flora, and fauna. The Caspian forests cover about 3 500 000 hectares. The Iranian Oak (*Quercus castaneifolia* C.A.MAY). is one of the most important commercial tree species in the Caspian forests in the North of Iran. It covers about 7% of the productive forest area and about 6.6% of the standing volume. It is mixed with Hornbeam (*Carpinus betulus* L.)and forms the Oak-Hornbeam association (Querco-carpinetum).

This study was carried out in the eastern and western part of the Caspian forests, and it is based on L. Emberger,s Pluviothermic Coefficient.

FOREST FLOOR ACCUMULATION AND THE NUTRITION OF PINUS PATULA IN THE USUTU FOREST, SWAZILAND.

Andrew R. Morris
Forest Research Manager
Usutu Pulp Company, Swaziland.

SUMMARY

FDC: 548: 424.7: 238: 174.7 Pinus patula Schl. et Cham.

The accumulation of dry matter in the forest floor under Pinus patula (Sclect. & Cham.), grown without thinning on short rotations of 16-18 years, can occur at rates of upto 5.8 t ha^{-1} yr^{-1}. Rates of accumulation are greatests at higher elevations such that the forest floor mass at rotation age (17 years) under first rotation crops is 42 t ha^{-1} at 1150 m a.s.l. compared with 78 t ha^{-1} at 1450 m a.s.l.. Nutrients, particularly N, that are immobilized in the forest floor at higher elevations significantly increase demand on soil nutrient supplies in the second half of the rotation (Table 1).

TABLE 1: Nutrient accretion (kg ha^{-1} yr^{-1}) into biomass and forest floor of Pinus patula pulpwood plantations from age 10-17 years.

	N	P	K	Ca	Mg
Biomass (all sites)	20.6	3.6	15.7	12.7	3.5
Forest floor (1150 m asl)	5.2	0.3	0.3	0.8	0.4
Forest floor (1450 m asl)	76.0	4.1	4.6	11.0	5.2

Evidence from fertilizer trials suggests that this immobilization of nutrients results in nutrient deficiencies of N, P and Ca which limit growth in the second half of the rotation, particularly at higher elevations.

A residue of forest floor is carried over from each rotation, even when slash is partially burnt after harvesting, such that the dry matter under mature second rotation stands can reach 200 t ha^{-1}. This continued acumulation of forest floor could influence the long term productivity of successive rotations in the Usutu forest.

GROWTH INTERACTIONS AND COMPETITION IN JUVENILE MIXED STANDS OF LODGEPOLE PINE AND ASPEN IN WESTERN ALBERTA, CANADA

S. Navratil
Research Scientist
Forestry Canada
Northern Forestry Centre
Edmonton, Canada

FDC: 231: 176.1 Populus tremuloides Michx.: 181.41: 174.7 Pinus contorta Dougl.: 181.65

After harvest of lodgepole pine (*Pinus contorta*) and lodgepole pine-aspen (*Populus tremuloides*) cover types, aspen density in regenerated stands increases due to prolific aspen regeneration by suckering from the root systems of sporadic aspen trees in the original stands and by natural seeding.

The increased aspen density in juvenile stands has caused concerns about:

a. the effects of aspen competition on growth of pine,
b. the need, timing and intensity of conifer-release treatments, and
c. the development of juvenile mixed stands.

Using the data from approximately 1,500 crop-tree centred plots, collected in 7 to 20 year-old mixed stands, we related the amount of competition surrounding a crop tree (pine) to the differences in pine growth. The "best" predictors of pine growth were selected by ranking 58 competition variables (based on number, size, growth and proximity of competitors) and the known competition indices (eg. those developed by Braathe, Pielou, Brand, Wagner, and Delong).

For operational use the best, and simplest competition indicators were percent aspen cover on a plot, and percent overtopping of a crop tree. The thresholds of aspen cover which reduced pine growth were 50-80% (higher at younger ages) for height growth, 30-40% for radial growth, and 30-40% for tree volume. Aspen cover greater than 50% resulted in a considerable, 50-80%, crop tree volume reduction. There was evidence of the positive nurse crop effect of aspen admixture on growth of pine in plots with 10-20% aspen cover.

A preliminary version of a model that quantifies the impact of competition on the maximum potential growth of pine has been developed. Current efforts are directed at adding functions for competition dynamics and mortality in mixed stands.

INFLUENCE OF SOIL ORGANIC MATTER CONTENT ON THE RESPONSIVENESS OF *Eucalyptus grandis* TO NITROGEN FERTILIZER APPLICATIONS

By A D Noble and M A Herbert
Senior Silviculturists

Institute for Commercial Forestry Research
Unversity of Natal
P O Box 375
Pietermaritzburg 3200
Republic of South Africa

ABSTRACT

FDC: 114.35: 114.54: 181.34: 232.322.411: 176.1 Eucalyptus grandis

It is widely recognised that the inherent nitrogen (N) mineralization capacity of a soil is directly related to the organic matter (OM) content. Consequently, in estimating the nitrogen requirements of *E. grandis* at planting this mineralization potential must be taken into account in order to obtain a judicious and cost effective use of inorganic nitrogenous fertilizers. This study was conducted to determine the relationship between OM content in the topsoil and the responsiveness of *E. grandis* to N fertilization applied at planting. The relative stem basal areas at breast height and N content in the leaves were measured in four different N-P-K fertilizer trials. Soil OM contents were determined on each of the sites and regression analysis undertaken. A highly significant inverse relationship was observed between the OM content of the soil and the relative basal area response to applied N. Soils with a low (< 2%), intermediate (2-5%) and high (> 5%) OM content were effectively associated with average relative responses of 55%, 24% and 5% respectively. Topsoils with an OM content of 2-5% and > 5% required 52 and 26 kg N ha^{-1} (40 and 20 g N per tree) respectively to obtain maximum fertilizer efficiency. A highly significant quadratic relationship was observed between OM content and N levels in the leaves of *E. grandis*, indicating a critical N level of 2.9%. These results clearly show the influence of OM on the response to N fertilization and N levels in the leaves of *E. grandis*.

Additional Key Words: Foliar Nitrogen, Site Quality.

INVESTIGATION ON OPTIMAL SPACING OF SCOTS PINE IN INTENSIVE CULTURES

Dr.Stevo ORLIC

Sumarski Institut
JASTREBARSKO, Yugoslavia

FDC: 238: 232.43: 174.7 Pinus sylvestris L.

An experiment with Scots Pine (*Pinus silvestris* L.) was laid out in the spring of 1966 .The following five spacings (in meters) were applied :

A: 1 x 1; B: 1,5 x 1,5; C: 2 x 2; D: 2,5 x 2,5; E: 3 x 3

The experiment was established according to the block system with randomly distributed treatments in four replications.

In the autumn 1988. the third inventory took place and the following variables were measured : total height of the trees, the height of the first living branch and the diameters at 0,30 m, 1,30 m and 2,30 m above the ground.

On the basis of the results obtained, it was shown that the effect of spacing was not significant on height, but it was highly significant on the diameter (dbh) and on slenderness (h/d) of the bole.

	Treatments					F
	A	B	C	D	E	
Height (m)	11,18	11,32	11,74	11,64	11,99	1,49 NS
Diameter (cm)	9,12	10,89	13,01	15,43	17,91	78,94 **
h/d	126,80	108,60	93,00	78,00	68,60	66,75 **

F tab. (4, 12) : 3,26 (= 5%); 5,41 (= 1%)

ENERGY PRODUCTION ON SMALL TROPICAL FARMLANDS

E.O. Videla PILASI

Forest Biogeocenology Scientist
Botanic Garden
SANTISIMA, Trinidad; ASUNCION, Paraguay

FDC: 91: (213)

This project applies in the total spirit of MAB 10 (Tendencies in the Investigation and in the Application of the Science and the Technology, and in the Application of the Science and the Technology for the Development of Arid Zones).

In the context of : Silviculture, agrotechnology, social, political and cultural factors; productivity and regeneration of grazing land; settlement and urban development (peoples dynamics).

Paraguay, is a country peculiar in South America for its biogeocenological characteristics and bioclimates. Its rich forests, agricultural and grazing lands are unique in the central Rio Plata catchment (watershed).

In Paraguay there are model programs in agroforestry used in Africa through ICRAF (International Council of Research in Agroforestry), Kenya, under the title: "PLANTS, EATING FROM MANY TABLES UNDER THE SAME SKY".

Within this project are the following sub-projects:

I. Agroforestry activities and rural development ;
II. Urban agrosilviculture;
III. Silviculture for firewood and energy for food (those three structural levels);
IV. Evaluation of tropical forest lands and land use planning;
V. Silviculture of arid zones and the struggle against desertification.

This project has for a setting to create in Paraguay twelve forestry centres and a network of agrometeorology stations.

This project will link CATIE of Costa Rica; with "Habitat" of the University of Loja, Ecuador; in Perù : Experimental Farms for Agrotechnical Education of Mid-level; with Brazil: Environment State Secretary.

On the African continent, with ICRAF in Kenya; with the Forestry Action Plan in the Tropics of the FAO, especially for Tanzania, Ethiopia, Uganda (Kampala).

This contribution to IUFRO is justly illustrated by an appendix of coloured pictures which are being applied to the attention on forest indigenous species under promising mixing agricultural cropping selections.

COMPARATIVE AUTOECOLOGICAL STUDY OF PINUS NIGRA ARN. SSP. SALZMANNII IN THE IBERIAN PENINSULA AND OTHER SUBSPECIES OF THE CIRCUM-MEDITERRANEAN REGION
(Estudio autoecológico comparativo de Pinus nigra ssp. salzmannii de la Península Ibérica y otras subespecies de la Región Circun-mediterránea)

FDC: 181: 174.7 Pinus nigra Arnold: (4-015)

P. Regato-Pajares, R. Elena-Rosselló y O. Sánchez Palomares
Becario de Investigación, Investigador Principal e Investigador Principal
Departamento de Sistemas Forestales, CIT, Instituto Nacional de Investigaciones Agrarias (I.N.I.A), Madrid, Spain.

The ecological significance of mediterranean pine forests and their status as native plants are controversial questions which have resulted in much misinterpretation and ignorance of their role within plant communities. The concept of climax community is of little use in the mediterranean region, and should be abandoned in favor of a more dynamic view of the processes which influence vegetation structure.

Pinus nigra serves as a good example, given its importance in mountainous areas throughout the mediterranean region where its various subspecies are found. Among these distinct subspecies, great adaptive similarities may be observed in comparative phytoecological analysis.

The autoecological features of Iberian subspecies have been defined after an extensive field survey recording climatic, edaphic, vegetational, and silvicultural data throughout its distributional range. The central distribution nucleus has been more intesively surveyed in order to study in greater depth the dynamics of the Pinus nigra community and its role in succession. Comparisons with other subspecies throughout the mediterranean region have been made, particularly with the ecologically more similar ones (Ssp. laricio, ssp. pallasiana and ssp. dalmatica).

This species defines potential forest stands under suitable climatic conditions at both extremes of the mediterranean region (Greece/Turkey and the Iberian peninsula). It also occupies sites of extreme severity both geomorphologically (rocky outcrops and steep slopes) and lithologically (dolomites, serpentines, etc.), where it may sometimes play an important edaphogenetic role. Our results showed more than 50 % of low evoluted soils (Rendzinas). In addition, it forms secondary pine stands which have expanded their range due to human activity.

Pinewoods consisting of different subspecies show quite similar understories. Nevertheless, it is possible to define two community types:
a) Submediterranean: with abundant deciduous species, but under drier environmental conditions than the marcescent communities.
b) Stepic cold mediterranean: with a cushion scrub appearing mainly in eastern and western regions, occupying even the highest mountainous forest belts.

The intense biogeomorphological dynamism of these mountainous areas causes constant natural modifications, defining a mosaic of communities in which Pinus nigra has a great ecological importance.
(Research supported by I.N.I.A. /R.P. n. 8148)

ON A MORE CONSCIOUS UNGULATE GAME HABITAT MANAGEMENT VIA FOREST CUTTING-REGENERATION-TENDING-EFFORTS AND STRATEGIES IN CENTRAL EUROPE

F. REIMOSER

Forschungsinstitut fuer Wildtierkunde
der Veterinaermedizinischen Universitaet
Vienna, Austria

FDC: 149.6: 156.5: 156.2: 62: (4)

In Central Europe (especially Austria, Germany, Switzerland, Yugoslavia, Czechoslovakia, Hungary and parts of Northern Italy) game damages on forest (browsing, peeling, fraying) done by red deer, roe deer and chamois are a great problem. Lack of shooting off ungulate game and other mistakes by game management relating to hunting were discussed intensively. However, the great influence of forestry measures (especially different silvicultural techniques) to the interrelations between forest, game and game damage was not conscious in forestry and scarcely investigated. Now in some areas game habitat management is taken into account in view of changing forest practices for reducing forest predisposition to game damage. During the last 15 years the author of the paper on hand investigated forest-ungulate-interactions and tried to find out the most important silvicultural factors influencing forest's predisposition to game damage. Some general principles are shortly summarized:

1. Game damage results from both browsing-peeling-fraying-stepping-pressure of game on forest (frequency of plants used by game) and predisposition of forest (habitat) to game damage. Game damage (GD) gains by increasing frequency (F) of game used trees as well as increasing predisposition (P) of forest; (GD = F . P).

2. Frequency of game used plants (F) depends on game density (D), average using frequency per animal and day (Fm) and staying period in days (t); (F = D . Fm . t).

3. Predisposition of forest results from both settling attractiveness (settling stimulus) of the habitat for game and available feeding. The ratio (quotient) of both is decisive. Predisposition (P) gains by increasing habitat attraction (HA) and by decreasing available food (AF); (P = HA/AF). Saisonal food composition and regeneration aim of forestry are important.

PREVENTIVE SILVICULTURE TO CONTROL BARK BEETLES IN THE PINE FOREST OF HONDURAS

José Reyes Ch. and C. Groothousen

Silviculturists
National Center for Applied Forest Research (CENIFA)
SIGUATEPEQUE, Honduras

FDC: 242: 412: 453: 145.7 Ipidae: 174.7 Pinus oocarpa Scheide:
174.7 Pinus caribaea Morelet

This study recommends the use of thinning as a silvicultural treatment for preventing attacks of bark beetles in pine stands of *Pinus oocarpa* Schiede and *Pinus caribaea* Morelet in Honduras.

The recommendation made is based on field data, which compared the response of trees to bark beetle attack, in both thinned and unthinned plots. The reference data were collected from permanent sample plots located in the forest regions of Comayagua, Yoro and Olancho since 1976.

The recommended management regime for the control of outbreaks puts emphasis on fire protection and the practice of two thinnings of medium intensity. The first thinning is carried out from below at 15 years of age removing about 40% of the current basal area. The second thinning removes about 40% of the basal area increment from the first thinning. This will result not only in healthy resistant trees, but also in better quality timber at the end of the rotation period.

EFFECTS OF FERTILIZATION, LIMING AND ACIDIC PRECIPITATION ON THE GROUND VEGETATION OF FORESTS IN SOUTH GERMANY

H. Rodenkirchen, Institute of Soil Science, University of Munich, Amalienstr. 52, D-8000 München 40, West Germany

FDC: 237.411: 237.417: 181.45: 425.3: (430.1)

Nitrogen fertilization with nitrochalk (100-150 kg N/ha per occasion) has been used since the fifties in older, formerly litter-raked pine forests of South Germany to improve stem wood production and soil fertility. Differences in the vegetation were observed when fertilized and nonfertilized plots were compared. The effects on ground vegetation were dependent on the specific site and stand conditions, increased when treatment was repeated and were more accentuated for higher doses. New nitrophilous species often from clearcut areas (e.g. Epilobium angustifolium, Rubus idaeus) immigrated and expanded for some years. The grass Deschampsia flexuosa was mainly promoted on loamy soils and further increased after additional thinning. Refertilization and higher doses decreased the cover of dwarf shrubs (Vaccinium myrtillus, Vaccinium vitis-idaea, Calluna vulgaris). Some forest mosses (e.g. Dicranum undulatum, Ptilidium ciliare, Bazzania trilobata) and reindeer lichens (Cladina sp., Cetraria islandica) seemed to be stronger damaged by urea and $(NH_4)_2SO_4$ than by nitrochalk. Additional lime and P (K,Mg) dressings increase the number of pretentious herbs and prolong the duration of the nitrogen effect. Intensively rooting and productive herbs and shrubs improve the litter quality and enhance the biological incorporation and cycling of nutrients.

Repeated vegetation surveys in non-fertilized pine forests with nearly constant light regime have shown, that more nitrophilous, but acid tolerant species (e.g. Deschampsia flexuosa) have expanded in the last decades. Positive changes have also been observed with bryophytes being indicators for better humus forms (e.g. Polytrichum formosum). Increased nitrogen deposition and the natural succession after termination of litter removal were the probable reasons.

In a N-saturated spruce forest (Experiment "Höglwald") the herb species Oxalis acetosella showed a very limited growth, correlated with a nutritional disorder (chlorosis, low Ca contents, high N and Mn contents) which could be removed by liming. Simulated sulfuric acid rain (pH 2,8) further impaired the Ca-nutrition and growth of Oxalis and induced a "die off" of dominant moss species (e.g. Thuidium tamariscinum). Only few acid tolerant bryophytes (Lophocolea heterophylla, Hypnum cupressiforme) utilized the empty niches and increased their extention. Liming was able to moderate or delay the acid rain effects.

ANALISIS DE PROCEDENCIAS DE *Acacia mangium* DE COSTA RICA

R. Salazar
CATIE, Turrialba
Costa Rica

FDC: 232.12: 176.1 Acacia mangium: (728.6)

Este estudio de 15 procedencias de *Acacia mangium* forma parto de los ensayos que estan siendo coordinados por SCIRO a nivel internacional. Las procedencias en estudio presentan un ranfo de 9° en latitud sur y 145 m en elevación (de 5 a 150 msnm). El ensayo fue establecido en 1984 en Costa Rica en el sitio Santa Clara a 170 msnm, con 3400 mm de precipitación y 25.7 °C de temperatura promedio; y en el sitio Puriscal a 960 msm, 2470 mm de precipitación y 22.3 °C de temperatura media. De utilizó un diseño de blogues completos al azar, 5 repeticiones y parcelas de 36 árboles plantados a 3x3 m.

En Santa Clara se probaron 14 procedencias y en Puriscal 6. Los resultados a los 4 años de edad mostraron en Santa Clara diferencias de 71% y 43% en altura total y dap, mientras que en Puriscal las diferencias fueron de 20 y 52% respectivamente. Las mejores procedencias fueron la de Morehead de Papua Nueva Guinea; Abergowrie y Claudie Rires de Queensland, Australia.

OUTLINE OF CYCLIC EROSIONAL-PYROGENIC THEORY OF COMMON-PINE NATURAL RENEWAL

S.N. SANNIKOV
Leading Scientific Worker
Academy of Sciences
Institute of Forest, Ural Division
SVERDLOVSK, USSR

FDC: 116: 181.43: 181.5: 231: 174.7 Pinus L.

The basic theses of the cyclically erosional-pyrogenic theory of the natural renewal of common-pine populations can be derived on the basis of the fundamental idea of the cyclic dynamics of all processes in the sun and of postulates concerning geographic covering of the earth and postulates concerning the patterns of erosional and forest-fire cycles as well as the xeromorphism of pine needles as a pre-adaptive property. As a result of evolution during the late Cenozoic (with a sharply increased climatic continentality and variability) in qualitatively different ecological niches alternating in time or in space - open eroded habitats (mineral substratum) and continuous burns (burned organic substratum) - pine adapted to the conditions of two niches.

Therefore, it has the status of a pioneer-exploratory species with a dual nature : on the one hand, that of a petro-psamophyte capable of renewal and survival on detrital-gravelly and sandy substrata and, on the other, that of a pronounced pyrophyte well adapted to self-renewal and stable existence in the "fire" environment. The cyclic character of erosional processes and fires leads to a regular cyclic processes of the natural renewal of pine populations.

The major logical consequences of the erosional-pyrogenic theory of pine evolution and renewal are fully borne out by the facts. This suggests the adequate validity of the theory and, consequently, its suitability for systematizing and explaining known and predicting new patterns in the self-reproduction, the structure and functions of pine populations, and also for the development of silvicultural measures for the improvement of pine forest renewal.

CONSTRUCTION OF BIOMASS TABLES IN TURKEY

Dr.Nedim Saracoğlu
Faculty of Forestry
Karadeniz Teknik University
Trabzon, Turkey

FDC: 537: (560)

In our country, there is a total 4 million ha of coppice forests. It is a very important activity which is as important as forestation in the improvement of degraded coppice forests and converting them into productive energy forests in order to meet the fuel requirements which are increasing continually in our country, to prevent the destruction of productive high forests, therefore to supply more wood raw material for the forest industry which at present operates with low capacity. As of the end of 1988, 390.000 ha of energy forest have been established.

In this study constructed dry-weight tables are the first examples on this subject in Turkey. It can be possible to learn the dry-weight of different components (stem, stem bark, live branches, twigs and leaves) and whole tree of Alder (Alnus glutinosa Gaertn. subsp. barbata (C.A.Mey)Yalt.). Dry-weight tables constructed by means of the material collected on the 86 sample tree were choosen in 19 trial plots in the east the Black Sea region within 10 m-1510 m altitude girdle. Sample plots were established 0.04 ha in size in stands of various maturity stages and site and density classes within the specified population.

All the field and laboratory work data were recorded on Fortran Coding Forms in Trabzon and computed at the Petawawa National Forestry Institut / Canada with Alemdag's model.

SITE EVALUATION IN BLACK WATTLE WITH SPECIAL REFERENCE TO SOIL FACTORS

A.P.G. Schönau and W.J.K. Aldworth
Silviculture Section
Institute for Commercial Forestry Research
University of Natal
Pietermaritzburg, South Africa

FDC: 114: 181.65: 176.1 Acacia mearnsii De Wild.

Together with climate, soil characteristics are the most important factors affecting tree growth. However, the attempts in many site evaluation studies to establish a direct relationship between soil factors and tree growth have not been very successful. The exception being soil depth which has been shown to be of general significance, especially in studies over large regions. Only in detailed studies of limited areas has it been possible to show the important role of other soil characteristics. Grouping or stratification of data according to soil groups has in some cases been able to improve these relationships.

In a study with black wattle (*Acacia mearnsii*) it is shown that more than 90% of the variation in tree growth can be explained by soil factors when the data are grouped according to a higher order of soil classification. Further investigations revealed that satisfactory results can be achieved by pooling the grouped data for various soil forms of the South African Binomial Soil Classification and using dummy variables for these and interactions between these and the important soil characteristics. These results are of practical application in predicting growth potential for afforestation of non-forest land, since the individual soil characteristics have to be determined for any meaningful site/soil survey.

Keywords : Soil classification, soil chemical levels, soil physical charcteristics, *Acacia mearnsii*

WALDBAULICHE GRUNDLAGEN DER LIBANONZEDER (CEDRUS LIBANI) IM WESTTAURUS/TÜRKEI

E. Senitza
Univ.f.Bodenkultur, Wien, Austria

FDC: 18: 62: 174.7 Cedrus libani A. Rich

Vom Gesamtvorkommen der Libanonzeder liegen die weltgrößten, geschlossenen Reinbestände (ca. 25.000 ha) im Westtaurus zwischen Antalya, Fethiye, Acipayam und Burdur mit Schwerpunkt in der Beydaglari Hauptkette südlich von Elmali (1300-2000m Seehöhe).

Ziel dieser Arbeit war ausgehend von einer Gesamtdarstellung der Literatur über *Cedrus libani* und einer Beurteilung der ökologischen Verhältnisse im Untersuchungsgebiet bei Elmali (District Antalya), die natürliche Bestandesentwicklung auf den wichtigsten Standortstypen zu analysieren, um ein waldbauliches Konzept als Grundlage für eine naturnahe Bewirtschaftung dieses Waldgebietes abzuleiten.

Prägend für die Wirkung und Bedeutung der ökologischen Einzelfaktoren sind spaltengründige Schutt- oder Blockstandorte, sowie das mediterrane sommertrockene und winterkalte Gebirgsklima. Für die Verjüngung entscheidend ist die Hangstabilität wegen der mit der Neigung zunehmenden Schäden durch Rollschutt und Schneeschub. Für das Baumwachstum wichtigster Faktor ist die Wasserversorgung durch nach der Schneeschmelze gespeichertes Bodenwasser.

Auf den ausgeschiedenen Standortstypen wurden 44 Naturwaldbestände untersucht und hinsichtlich Bestandesstruktur, Konkurrenzdruck, Ausscheidungstendenzen und Entwicklungsdynamik analysiert. Aus den Einzelbaummerkmalen konnten Bestandeskennziffern abgeleitet werden, welche Kriterien der Entwicklungsphase, der Bestandesdichte und der Ertragsklasse unabhängig voneinander beschreiben. So ließen sich sowohl Entwicklungsphasen voneinander, als auch standortsbedingte Strukturunterschiede statistisch unterscheiden.
Aus diesen Ergebnissen ließen sich typische Entwicklungsreihen von Initial- bis zu Terminal- und Zerfallsphasen bilden. Diese Entwicklungsreihen konnten sowohl hinsichtlich Bestandesdichte und Horizontalstruktur, als auch in ihren dynamischen Merkmalen, sowie Verjüngungsökologie charakterisiert werden. Daraus konnte eine ertragskundlich und waldbaulich differenzierte Beurteilung der Naturwaldentwicklung abgeleitet werden, die wertvolle Hinweise auf gezielte Bestandespflege- und Verjüngungsverfahren bietet.
Entsprechend den unterschiedlichen verjüngungsökologischen Verhältnissen auf den Standortstypen treten differenzierte Varianten der Entwicklungszyklen auf.

Das waldbaulichen Behandlungskonzepts schlägt den Standortstypen entsprechende Zielsetzungen (Wirtschaftswald / Schutzwald) mit abgestimmten Verjüngungsverfahren (Schirmschlag ev. mit Bodenfeuer, Saat, Femelschlag) sowie an der Naturwaldstruktur und Entwicklungsdynamik orientierte Bestandspflege vor.

Senitza, E., 1989: Waldbauliche Grundlagen der Libanonzeder (*Cedrus libani* A. Rich) im Westtaurus/Türkei. VWGÖ - Wien, Dissertationen der Univ.f.Bodenkultur in Wien, Band 34, 225 p.

F I R E   I N   B R A Z I L I A N   F O R E S T S

Ronaldo Viana Soares

Professor, School of Forestry

Federal University of Paraná
Curitiba, Paraná, Brazil

S U M M A R Y

FDC: 431: (81)

Forestry in Brazil started to experience a solid development in the years 60. The development of silviculture methods and the establishment of millions of hectares of planted forests increased the concern of forest managers regarding fire occurrence. The first big wildfire recorded in the country burned around two million hectares of forests, second growth trees, and grasslands in the southern State of Paraná in 1963. This fire is considered the initial landmark of fire studies in Brazil. However, only in 1983 the first survey was carried out in order to collect statistics on forest fire occurrence in the country. Potentially, the large areas covered with savanna in central Brazil present the highest risk of forest fires: about 55% of the days in a year are rated as high and very high fire danger days. Regarding the geographic regions, the Southeast presented, between 1983 and 1987, the highest number of fires and the largest burned area. Debris burning and incendiary were, respectively, the two leading causes of fires. In the North region, where the Amazon forest grows, fire is not a primary source of damage to the forests. The big fires recorded (and worldwide announced) in that region in 1988 were in fact land cleanning burns, i.e., the fires were set after the trees were felled, since in natural conditions the moist and luxuriant forest won't burn.

BIOMASS EQUATIONS FOR *PINUS BRUTIA* IN NORTHERN ISRAEL

Stanturf, John A. (Pennsylvania State University, USA) and Spettir, Ernst (Keren Kayemeth LeIsrael, Kiryat Hayim, Israel)

FDC: 537: 174.7 Pinus brutia Ten.

In the late 1960s, *Pinus brutia* Ten. replaced the native Aleppo pine (*Pinus halepensis* Mill.) as the principal afforestation species in the hilly Mediterranean region of northern Israel . While the native Aleppo pine had many advantages, its poor growth form and susceptibility to *Matsucoccus* attack caused foresters to shift to species with resistance to the scale. *Pinus brutia* is native to the eastern Mediterranean basin, and has replaced Aleppo pine on most sites. These plantings have been primarily for amenity and erosion control, thus little is known about the productivity of these stands. As part of an effort to stratify productivity potential on different soil types, we sought to develop equations for above-ground biomass of individual trees. Trees of different ages (15 to 27 years) on contrasting Terra Rossa (dolomitic limestone) and Rendzina (hard chalk) soils were felled; sectioned into bolewood, coarse branches, fine branches, cones, and up to three age classes of needles; and weighed green. Samples of each type of material were dried and weighed. Logarithmic regression equations were developed, with height and either diameter at breast height (1.37 m) or stump diameter as predictor variables. These equations were applied to biomass data from natural *Pinus brutia* stands in southern Turkey with good results.

ESTIMATION OF ENVIRONMENTAL CONSERVATION EFFECT FOR THE EXISTING URBAN AND SUBURBAN FORESTS IN JAPAN

Dr. Masanori SUYAMA
Director of Silviculture Division
KANSAI Research Center, For. & Forest Prod. Res. Inst.
Kyoto, Japan

FDC: 270: 266: 116.64

Forest not only produces timber, but also offers us a comfortable environment by cultivation of water source, filtration of air and water, and controls flood or landslide.

In Kansai district and metropolitan area of Japan, there are many urban and suburban forests. Most of them are man-made forests of Sugi (Cryptomeria japonica) and Hinoki(Chamaecyparis obtusa); and natural forests of Akamatsu(Pinus densiflora) or some broad-leaved tree species. We fear that they would inflict big damages to the surrounding residents, when the natural disasters such as landslide, rockslide(falling rock), and debris flow(mud flow) have once occurred. Consequently, many people place their hopes on more urban and suburban forests than deep mountain forests, as an effective prevention measure for the natural disasters.

In general, it confirmes that trees are used to control erosion on slopes, to stabilize landslide scars, and to absorb debris flow impacts. Roots, due to their tensile strength and frictional or adhesional properties, reinforce the soil, increasing soil shear strength. Particularly, the tree roots may anchor into firm strata providing support to the upslope soil mantle through buttressing and arching. By binding the soil particles at the ground surface, roots reduce the susceptibility to soil erosion. On the other hand, standing woods exhibit a shock absorber function when they are made an impact by debris flow or rockslide.

The authors will take up the latest topics about the effect of environmental conservation function of forest from the above mentioned point of view. We will report on the results of our survey of the actual situation of urban and suburban forests and we will discuss the mechanical evaluation method for the beneficial factors to slope stability by urban and suburban forests.

ALLEY CROPPING AS A SUSTAINABLE PRODUCTION SYSTEM IN THE CONDITIONS OF TURRIALBA, COSTA RICA.

Sanchez, G.A., Sanchez,J. and Viquez, E.

Nitrogen Fixing Trees Project
CATIE, TURRIALBA, Costa Rica.

FDC: 238: 261.9: 181.41

Alley cropping is a production system in which fast-growing trees are associated with annual crops such as maize and beans and which has been characterized as a low-input production alternative. In this system, the annual crops are grown between rows of woody shrubs or fallow trees, which are pruned periodically during the cropping period to reduce shading and provide greenmanure to the associated crops.

The present research had the objectives of :

1) developing a quantitative methodology to determine the stability of and the degree of decline of yield and other factors associated with the alley cropping production systems, and

2) establishing the amounts of nutrient reserve and recycling using two field experiments set up at the Tropical Agriculture Research and Training Enter (CATIE) in Turrialba, Costa Rica, in 1982 and 1984

It was found that increasing the population of trees in an alley cropping system results in increased yield stability of maize. However, factors other than the level of soil nutrients cause the increase stability to be associated with lower average yields.In Turrialba, the best spacing for *Erythrina poeppigiana*, in an alley cropping system with maize, was found to be 6m x 2m as this spacing resulted in greater yield stability, acceptable overall yield levels, and tendency for these yields to increase over time.

The reserves of phosphorus in the tree component were shown to be of especial significance, accounting for 0.45 of the total reserves of the system. *Gliricidia sepium* showed a markedly response when Nitrogen was applied to the associated crop; by the contrary, *E. poeppigiana* showed a decrease in biomass yields and nutrient reserves. These results suggest that *G. sepium* may represents competition with the crop for soil nutrients in an alley cropping system. Despite the rapid rate of nutrient recycling, some evidence indicated that nutrients other than N, such as Phosphorus and Potassium, may become limiting in an alley cropping system in which productivity is high as when N was applied crops associated with *G. sepium*.

STUDY ON SHEARING FORCE AND IMPACT FORCE OF A VOLCANIC MUD FLOW ON MT. SAKURAJIMA

Dr. Yoshinobu Taniguchi
Professor of Agriculture and Forest Scieces
Faculty of Agriculture, Miyazaki University
Miyazaki, Japan

FDC: 116.2/.3: (52)

This study was carried out to determine the size of the actual shearing force of a volcanic mud flow on the surface of a channel bottom, and to make clear the mechanism of the destruction and abrasion of a concrete channel in torrents of Mt. Sakurajima.

A field survey was conducted in the Arimura River and the Mochiki River using two kinds of shearing stress meters (type A and type B). It was impossible to obtain data using the type A meter. However, some data were obtained in the Arimura River and the Mochiki River using the type B meter. The results of the survey showed that the actual shearing force on the surface of a channel bottom was $0.5 \sim 2.5 kgf/cm^2$. On the other hand, the theory of hydraulics showed that the shearing force on a scale of such a mud flow must be no more than $4 gf/cm^2$. The great large shearing force could be explained by the friction between stones and channel bottom. The size of a stone corresponding to the observed shearing force of $2.13 kgf/cm^2$ in the Arimura River's mud flow which took plce on September 24, 1988 was 80cm in diameter. The dimeters of the stones were measured on the screen of the video. The video tape was made by the Osumi Work Office. The maximum diameter of a stone was 3.8m.

One of the characteristics of Mt.Sakurajima's mud flows is a large impact force caused by collisions of stones with the channel bottom as well as the presence of other debris flows.In order to estimate the effect of this impact force which is a great cause of destruction of a channel, a converted diameter (i.e. the diameter of a stone giving rise to a dead load equal to its impact load) was calculated, using the theory of a collision of an elastic body. The maximum diameter was 9.4m in the case of the Arimura River's mud flow on September 24, 1988, supposing that the falling height of a stone was 10cm and the strain of concrete was 1mm. This has the same effect as a very huge stone loaded on a channel bottom. Channel works should be designed to take a great load into consideration.

The abrasion of a channel's concrete was also studied. Abrasion is another important factor in the damage of a channel from the view point of the shearing strength of concrete. The shearing strength of concrete is generally considered to be 1/7 of the compressive strength. Abrasion of concrete was observed by chance in the Mochiki River on October 6, 1988 after the channel work was completed. The abrasion was 2.5cm deep. It had been already determined that the compressive strength of the concrete on the 7th day after mixing had been about $110 kgf/cm^2$. If the scale of the mud flow had been equal to that of the Arimura River on October 6, 1988, the actual shearing force would have been $2.5 kgf/cm^2$. Judging from that, the shearing force is never small in comparison with the allowable strength of the concrete, especially if it is regarded as a repeated force. Abrasion was caused by such a mechanism in the channel of the Mochiki River.

INFLUENCE OF AIR POLLUTANTS ON VEGETATIVE AND REPRODUCTIVE GROWTH OF AVENUE TREES IN BANGALORE,INDIA.

K.R.Thimmaraju and T.Venkatesh Reddy,
Division of Horticulture,University of Agricultural Sciences,
G.K.V.K. Campus,Bangalore-560 065.

FDC: 176.1 Tamarindus indica L.: 181.52: (213)

Bangalore, a metropolitan city in India is considered as a garden city of India. It is one of the fast growing cities in the world. This beautiful city has a very rich collection of avenue trees, which are both indegenous and exotic. When it was a small city with limited population and less number of automobiles and industries, it was free of air pollution. These avenue trees added beauty to the city by their flowering during different seasons of the year. However, on account of increased population, automobiles and industries there has been a high degree of air pollution. In fact, many people in the city suffer from various allergy diseases, for which this high degree of air pollution is a contributing factor. Air polllutants will exercise adverse effects on the various stages of growth and development of plants, particularly on their reproductive biology. During the study it was observed that automobile exhaust gases along with dust particles were found to be important pollutants. Depending upon the density of traffic in the city, avenue trees were catagorised into three groups viz., those which are growing under highly polluted conditions, those which are growing under medium polluted conditions and others growing under conditions comparitively free of environmental pollutants, viz., public parks, and residential localities.

It was observed that the atmospheric pollutants in highly polluted areas induced defoliation, die back of shoots and reduction of flowering and fruiting. It was observed that inspite of sparse flowering, there was neglegible fruitset in the avenue trees under such conditions. It is quite likely that the pollutants may inhibit the germination of pollen grains on the stigma and there may be poor insect activity resulting in inadequate pollination and fruitset. The avenue trees responded in terms of varied degree of defoliation under highly polluted conditions. The only tree which was found to be highly resistant to atmospheric pollutants and continue to exhibit normal growth without showing any symptoms of defoliation or die back or poor flowering and fruiting is the neem tree (Azadirchta indica).

The further extension of such studies help to screen the avenue trees in terms of their response to varied levels of air pollutants, will help to identify more and more avenue trees that are resistant to air pollutants, which could be planted in highly polluted areas.

RESPONSE OF TAMARIND (Tamarindus indica Linn.) TREE TO ARID AND SEMIARID CONDITIONS.

K.R. THIMMARAJU AND K.USHA
University of Agricultural Sciences
Bangalore - 560 065, INDIA.

FDC: 181.45: 425.1: 273

Tamarind (Tamarindus indica) is an economically important tree crop of India. It thrives well in arid and semiarid conditions. It grows mostly in interior dry zones which is characterised by alternate wet and dry seasons. The vegetative growth, flowering and fruit development in this tree is confined to the wet, rainy season which extends from June to October months. The growth and maturity of the fruits takes place till the last week of January. From then onwards i.e. February to the end of March, there will be a dry season, which coincides the ripening of the fruit. With the advent of dry season, the tree starts shedding leaves and enters into a brief period of dormancy to overcome the consequences of soil moisture stress.

The tamarind tree after shedding the leaves enters into a brief period of dormancy. The sprouting of the buds and followed by flowering take place during the second half of the month of April. Though the dry conditions still prevail during the months of April and May still the receipt of off season showers during these months will provide conditions favourable for fruitset. It is very interesting to note that the tamarind tree is subjected to vagaries of monsoon it has a fairly long period of flowering starting from the second half of April upto the end of August month. This fairly long duration of flowering, in tamarind, should be considered as an adoptive mechanism and insurance against, the occurence of poor conditions for fruitset during monsoon. This clearly indicates that in tamarind its growth and production are very well adopted to the alteration of the wet and dry seasons. In case the tamarind is grown under intermittent rainfall without the alternation of wet and dry seasons, the tree continues to remain evergreen. It does not shed leaves, there will be continuous flowering and fuiting and at one time sizeable number of fruits will not be ready for harvest. Hence it is uneconomical to grow tamarind under such conditions.

Tamarind being a hardy, drought tolerant economically important tree crop free from severe pests and diseases, it is an ideal free crop, for the economic improvement of farmers inhabiting in arid and semiarid regions, which often experience the reoccurence of drought year after year worsening their economic positions.

Wall/Corner Fire Tests on Selected Wood Products

by

Hao C. Tran
Research Forest Products Technologist
U.S. Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53705-2398

Marc L. Janssens
National Forest Products Association
1250 Connecticut Avenue, NW.
Washington, DC 20036

SUMMARY

FDC: 812.143: 843.4--01

Mathematical modeling has become an important tool to assess the fire hazard in buildings, considerable research effort has concentrated on development of models. At the moment, models describe the contribution of burning contents and smoke flow phenomena. However, their capability is limited in predicting fires that extend to walls and ceiling. Our research is concentrating on developing algorithms to describe wall fire. Such algorithms can be incorporated into existing models to comprehensively describe realistic fires thereby increasing the capability to assess fire hazard of building fires and and improve life safety and reduce property loss.

The approach includes experiments to develop a data base of both bench-scale and full-scale data for model validation purposes and theoretical development of algorithms for wall fire. An ASTM proposed room test standard was used as the basis for the full-scale experiments to serve two objectives: (1) evaluate performance of a range of wood products in such a test and (2) provide sufficient data for model verification. In the first part of this research program, a sensitivity study was done to investigate the effect of variables such as the burner location, power output program, and types of wall lining on the compartment fire growth. From the sensitivity study, the optimal conditions were chosen in further testing of a set of wood materials having different flame spread characteristics.

In this report, the findings from the room fire tests are discussed. It was found that for both wall and corner fire tests conducted with the ASTM room test, the burner program of 40 kW for 5 min followed by 160 kW for an additional 5 min was appropriate. The mentioned burner setting presents two "challenge" levels that can separate different wood materials. Fire-retardant treated plywood and gypsum wall board did not flashover. Wood materials having low flame spread indices (class B and low C of ASTM E 84) required 160 kW to reach flashover. Materials having high flame spread indices (high class C) would flashover during the 40 kW exposure. Reference to the development of the data base of bench-scale data used as input to the developing model and status of the model development will be made.

EVAPORATION RATES FROM A FOREST CANOPY DURING STORM IN A HUMID REGION

YOSHINORI TSUKAMOTO
Professor, Department of Forestry,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183 Japan

FDC: 116.11: 116.13: (213)

The objective of the paper is to evaluate the evaporation rate on a forest canopy during storm by a water budget method considering that the major component of interception loss is direct evaporation from a canopy. The basic equation for calculation of the water budget of a tree is expressed as follows:

$$e = p - r - \Delta w/\Delta t$$

where e is evaporation from a tree, p is rainfall, r is runoff water from a tree canopy which is composed of droplets, throughfall and stem flow under a canopy and Δw is the change of weight of a whole tree. Among these components, p, r and Δw are measurable with a large raingauge, a large collecting pan of runoff water under a canopy and a weighing apparatus which measures the change of a tree weight, respectively, during storm. Consequently, e is caluculated for Δt = 1hr by the above equation. Measurement has been carried out for 2 years on 35 storms. 12 trees were used for the experiment.

The average value of maximum rainfall intensity(p_{tmax}) for t hr and the corresponding evaporation rate(e_t) are obtained to calculate (e_t/p_{tmax}). The relationship between (e_t/p_{tmax}) and t for various time intervals showed a nearly constant value for a respective storm. Most values of (e_t/p_{tmax}) of a storm converge in the range of 15 to 20% with longer t values.

The maximum 3 hr rainfall intensity of a storm is plotted against the evaporation rate of the corresponding 3 hr for various storms. The relationship is expressed by a linear line with a high correlation coefficient.

The analysis demonstrates that evaporation rates are closely related to rainfall intensity. To compare the result with previous investigations, the average evaporation rates of 3 hr maximum rainfall intensity are calculated as in the following. The result is almost equivalent to those of previous investigations.

Storm amount	<10mm	>10mm
Average rainfall intensity(mm/hr)	1.021	3.148
Average evaporation rate(mm/hr)	0.247	0.498

It is concluded that the evaporation rate from a forest canopy increases lineally with rainfall intensity for any periods during storm. The writers can not explain what atmospheric mechanism during storm causes this phenomenon. It seems to the writers that this phenomenon is deeply related to storm itself including large scale atmospheric disturbance.

ASSESSMENT OF PHOTOSYNTHESIS AND ATTRIBUTES IN TROPICAL TREE SPECIES DIFFERING IN BIOMASS PRODUCTION POTENTIAL

S.N.Vajranabhaiah, P. Chandrashekara Reddy, N. Swamy Rao
and S.R. Siddaraju,
Professor of Crop physiology, Asst. Professor of Crop physiology,
Assoc. professor of Farm Forestry and Research Associate.
University of Agricultural Sciences
GKVK Campus, Bangalore 560 065, India.

FDC: 537: 114.52: 114.351: (213)

Photosynthetic rate and associated parameters largely determine the accumulation of biomass in plants including trees. Tropical species growing in semi-arid regions under forestry and agroforestry programmes differ in the production of different kinds of biomass, which is often reflected in total dry matter. Estimates of photosynthesis, transpiration rates and other associated plant factors under a given set of environmental situations prevailing in these regions would reflect the species ability in biomass production. Hence, photosynthetic rate and attributes are determined in five tropical tree species.

Photosynthesis (A), Conductance (g_s) and transpiration rates in five tropical tree species were measured by using portable Licor (LI 6000) photosynthetic system. Chlorophyll and soluble protein were determined. Leaf thickness, mesophyll air space and carbonic anhydrase activity were assayed.

Acacia auriculiformis (15.11) and Eucalyptus 'hybrid' (14.44) exhibited higher 'A' values, followed by rest, least values were noticed in Derris indica (6.22). Conductances were high in Grevillea robusta (0.4163) and least values were in Derris indica (0.2206). A/g_s values were very high in Acacia and Eucalyptus. Total chlorophyll content was very high in Derris indica which was more due to higher chlorophyll 'b' content resulting in lower chl a/b ratio than in rest. Specific activity of carbonic anhydrase was high in Casuarina and Grevillea and low in Eucalyptus and Derris. Examination of transpiration, leaf thickness, mesophyll airspace suggest a relation of photosynthesis with transpiration in Eucalyptus.

High 'A' values in Acacia and Eucalyptus are associated with higher g_s values, where as lower values of 'A' in Casuarina and Grevillea inspite of high g_s suggest non stomatal factors to be limiting in the latter two. Derris with low 'A' and g_s seem to have stomatal and non stomatal limitations. Relation of other parameters with different species is being discussed.

BIOMASS PRODUCTION AND NUTRIENT COMPOSITION OF LEAF LITTER IN SOME SELECTED TROPICAL TREES

S.N.Vajranabhaiah, N.Swamy Rao and P.Chandrashekara Reddy
Professor of Crop Physiology, Assoc. professor of Farm Forestry
and Asst. Professor of Crop physiology,
University of Agricultural Sciences
GKVK Campus, Bangalore 560 065, India.

FDC: 161.32: 161.16: 537: (213)

Emphasis is laid on establishment of energy and agroforestry plantations, in semi-arid regions of the states like Karnataka, which are mono or mixed cultures. The species included in these programmes vary widely in their capacity to produce biomass. However there is need to evaluate the relative performance of some of the frequently planted tropical tree species and also mixed plantations.

Above ground biomass in five tropical tree- Acacia auriculiformis. A.Cunn., Casuarina equisetifolia. L., Eucalyptus 'hybrid' L. Herit., Grevillea robusta. A Cunn. and Derris indica (Lam.) Benn - and mixed plantations comprising of different species were investigated, at 5, 10, and 15 years of age. Nutrient composition of litter biomass of these plantations were also analysed and found to maintain almost similar pattern of differences, irrespective of age.

Production of litter biomass was higher in mixed plantation, followed by Eucalyptus and Grevillea in all observations. High bole volume was maintained in Eucalyptus, mixed plantation and Acacia at fifth and tenth year. Where as Derris and Casuarina produced lower volume. Fifth year values of total biomass were high in Eucalyptus, Acacia and mixed plantation which was maintained till fifteenth year. Whereas Derris exhibited lowest values on per hectare basis.

Calcium content in Eucalyptus and Grevillea, Potassium and magnesium in Grevillea were higher in leaf litter. Zinc was high in Eucalyptus and mixed plantation. Iron contents in leaf litter of Derris were high followed by Eucalyptus and others. Copper levels were also high in Derris followed by leaf litter of mixed plantation and others. Phosphorus contents did not differ.

Observed variations among the species in biomass production and nutrient composition are more conspicuous when expressed per unit land area. Further one time light interception studies indicate the greater penetration of light to different canopy levels in fast growing Eucalyptus and Acacia which may account for greater biomass.

RESEARCH OF WIND EROSION INTENSITY IN THE REGION OF SUBOTICA- HORGOŠ SANDS

Velizar Velašević and Ljubomir Letić

Forestry Faculty, Belgarde University, Yugoslavia

FDC: 116.4: (497.1)

In this study we have tried to give, based on our complex researches a contribution to the scientific solution of wind erosion problem in the part of the Pannonian Plain covering a part of the country between the Danube and Tisa rivers.

For this reason, in the region Subotica-Horgoš Sands, locality D. Tavankut two experimental stations have been set up, on the protected erosion field /location "Š"/ and on unprotected erosion field /location "P"/.

In the investigation of wind erosion processes the " Modified method of instrumental measuring" has been applied, and the results refer to the research period 198o- 1989. Investigations include the chronological observation of aeolian deposition quantity and the parameters of climate and soil, affecting the process of deflation.

The research has shown that in the region of Subotica-Horgoš Sands there develope the processes of wind erosion, as follows:

Average monthly intensities oscillate within the limits:

- at the locality "P" : I_{ee}= o.o4o -o.765 kg m^{-1} / IX-II/;

- at the location "Š" : I_{ee}= o.olo -o.o53 kg m^{-1} / XII-V/, with the maximum occurring in the period II-VI at both localities.

Chemical properties of the researched soils show that the Tavankut sands have got degrees of fertility. However, the relation between the content of some components of fertility observed in the soil(Oz) and in aeolian deposition (En) must be emphasied. It has been measured that:

- organic matter content in aeolian deposition/En/ is up to 16 times higher than in the soil(Oz);
- calcium carbonate content in aeolian deposition is 3.6 times higher in the soil (Oz);
- total nitrogen content in (En) is 14 times higher than in (Oz);
- the content of readily available phosphorus in (En) is up to 2o.3 times higher than (Oz) and
- readily available potassium content in (En) is up to 14.4 times higher than in (Oz).

The above data emphasize a very accelerated fertility decline in the endangered /sandy/ areas of the Subotica-Horgoš Sands.

RESULTS OF A Gliricidia sepium (Jacq.) Steud. PROVENANCE AND FAMILY TRIAL IN TROPICAL HUMID FOREST CONDITIONS

Viquez, E., Sanchez, G.A., Camocho, Y., and Jon Llap, R.

Nitrogen Fixing Trees Project,
CATIE, Costa Rica

FDC: 232.12: 176.1 Gliricidia sepium: 26: (213)

Agroforestry has been identified as an alternative for sustainable land use in the tropics. *Gliricidia sepium* (Jacq.) Steud,. a legume tree species native from Mexico to Panama throughout Central America, has shown potential in agroforestry for its multiple uses (fodder, mulch, firewood and living fence posts among others).

The present study started with the following objectives: to determine the amount of variation among provenances and families within provenances, and to select superior genotypes for the different agroforestry systems.

Seeds from a total of 177 families of 12 provenances were sown at CATIE's nursery and planted in the field using a nested design with 12 plants per family and 3 replications. All plants were completely randomized within a replication. The following parameters were measured ninety days after planting: total height, basal diameter, number of shoots, length of the largest branch, maximum number of leaflets and dry weight biomass

Significant differences among provenances ($P<0.001$) and families within provenances ($P<0.005$), were determined for all the variables except for basal diameter. Two provenances from Costa Rica had the highest biomass and total height values (84,94g and 84,35g,and 81,46 cm and 75,48 cm respectively) compared to two provenances from Mexico whith the lowest values (55,99 g and 55,57 g and 62,80 cm respectively). A greater variation (+80%) was observed among trees within a family for all the parameters.

A low correlation (R^2: 0,38 to 0,5) was detected between total height, maximum number of leaflets and dry weight biomass to number of dry months of the seeds origin. Higher values of R^2 were determined between seed weight and latitude, and seed weight and number of dry months (0,54 and 0,82 respectively).

A complementary work on the quality of the edible biomass was also carried out on this plant material. The parameters evaluated were: N, P, K, Ca, Mg, Cu, Zn and Mn content and *in vitro* digestibility. Nitrogen content values varied by 35% with maximum values of 46,4 g/kg and minimum of 30,2 g/kg. Similarly, a high variation (34% to 69%) was observed for the other elements. In vitro digestibility values were between 68% and 56%.

A second evaluation of growth parameters was done at the end of 1989 and the results will be used to verify the selection of superior genotypes.

NEW DATA ON THE HYDROLOGIC ROLE OF FORESTS AND WATERSHED MANAGEMENT

N. A. VORONKOV

Professor
State Pedagogical Institute, Moscow, USSR

FDC: 116.2: 181.312: 62

The paper presents newly found regularities of water cycling in forest and field ecosystems as well as a concept of the hydrologic role of forests, differentiated according to a set of factors (timber stand structure, hydrologic types of soil-grounds, precipitation rates, geographic conditions, etc..).

A system of activities is suggested for watershed management by means of exerting influence on forest communities, which includes control of the coniferous / deciduous ratio in the species composition, of stand density, age spectrum and distribution within catchment areas.

This study is based on the results of analysis and generalization of long-term (on some issues 20 to 30 years) stationary ecologic and hydrologic research in forest ecosystems and on watersheds in the forest, forest-steppe and steppe zones of the USSR.

It is shown that differences in evapotranspiration of individual forest ecosystems are more significant than those between forested and not forested catchment areas in their averaged values. That leads to the conclusion that there are great possibilities to manage water resources of forest watersheds without converting them into other uses.

It is possible to increase or reduce the input of water into water sources within 70 to 215 mm per year (the annual total precipitation amounts to 750 mm) only through controlling the forest species composition.

When the density of a spruce forest reduces from fully stocked to 0.6 stocking, the runoff may increase by 90 to 100 mm. It is possible to modify evapotranspiration within 50to 100 mm per year on the basis of age differences.

Approaches and ecologic methods have been developed to manage water resources on watersheds.

CZECHOSLOVAK FORESTS UNDER THE IMPACT OF AIR POLLUTION

M. Vyskot
Ordinary Member of the Czechoslovak Academy of Sciences
Professor, Dr. Ing., DrSc.
Institute of Systematic and Ecological Biology of the ČSAV
Brno, Czechoslovakia

FDC: 425.1: 425.3: 907: (437)

Forest dieback due to industrial pollutants is a quite new phenomenon yet unknown. Some damage has been observed even for a long time but the consequences, which had been initially little apparent, have broken out recently like explosion and have threatened well-developed parts of the world. In European industrial countries air pollution amounted to 523 million tonnes in 1960 and even 792 million tonnes in 1987. It is manifested remarkably with withering of long-aged forest communities.

In addition to local sources, remote transports of pollutants, which are borne thousands of kilometres from the place of their origin, have very unfavourable effects. The harmful substances get to higher atmospheric layers and are carried to considerable heights and distances by wind flows. In our country, summits and mountain lakes are damaged in the Tatras.

Air pollution represents a considerable threat to Czechoslovak forests not only from the point of view of wood production but it is responsible predominantly for tremendous environmental disturbances. It refers to damage to the forest functions in water management, soil conservation, climate and in the health effect. The western region of our country, especially the Ore Mountains, is afflicted catastrophically. The damage spreads also to the Orlické and the Jizerské Mountains,the Giant Mountains and the Beskids, likewise in Slovakia the regions of Žiar n.H., Rožňava and Lučenec are threatened. Even one third of forests dies back and by the year 2000 a serious threat is forecasted to more than a half of our forest wealth. It is necessary to realize that this irretrievable damage can be prevented only by a change in the technologies of industry and power engineering.

Simultaneously, there is the possibility of obtaining an important raw material such as, for example, sulphur compounds. Forestry can prevent direct only small damage by planting more resistant tree species, particularly broadleaved ones and some introduced conifers, by different amelioration approaches, above all of forest hydrological regime and some fertilization methods.

It is a global problem to be solved through close cooperation. Therefore, extension of the present international agreements by other effective measures is highly desirable.

ON THE STATUS OF SOIL NUTRIENTS UNDER TROPICAL RAIN FORESTS IN THE PENINSULA MALAYSIA

K. Waki
Professor
Faculty of Agriculture, Gifu University,
Gifu 501-11, Japan

FDC: 114.52: 114.351: (213)

To establish a silvicultural system for maintaining productivity of tropical rain forests, the analysis on nutrient conditions in forest soil ecosystems is necessary. In this study, nutrient status of soil profiles were investigated in four different areas of low land and hilly regions of the southern Peninsular Malaysia, and amounts of litter fall and nutrients have been estimated seasonally and annually under different Dipterocarps plantations. Further, to clarify the decomposition process of leaf litter, trials have been done in the same plantations by using litter bag method.

The results obtained here showed that 1) most of soils in tropical rain forests were acidic in soil reaction and very poor in nutrients, 2) the seasonal pattern of leaf litter fall varied with species and closely related to environmental conditions, 3) the disappearance rate of materials in litter bag placed on the ground related greatly to termite activities and less related to fungal attacks; leaf litter disappeared at rate from 65 % to 95 % of initial amounts for 12 months.

Considering these nutrient status in tropical rain forests, it is more desirable for maintaining forest productivity to keep multi-specific stand with a large number of different tree species than to cultivate a mono-specific stand, because forest litter fallen on the ground throughout a year should have the positive effects as a immediate source of nutrients, as a ground cover protecting the soil against moisture evaporation, and as a reducing agent of soil erosion due to the destructive impact by rain drops.

Acidic Deposition and Forest Decline - 60 Years of Soil and Tree Nutrition Research

E. H. White, D. J. Raynal, M. J. Mitchell, C. A. Nowak
J. P. Shepard and R. B. Downard Jr.

State University of New York College of
Environmental Science and Forestry
Syracuse, New York 13210, USA

Abstract

FDC: 181.45: 425.1: 425.3: 181.34

The impact of acidic deposition and forest development on nutrient cycling and productivity of growth decline in conifers was evaluated on the Charles Lathrop Pack Demonstration Forest in the southeastern Adirondack Mountains. The site has a known history of land use, 650 years of quantitative soil and tree nutrition data base, on existing potassium deficiency and soils predisposed to possible adverse acidic deposition effects.

Historical and contemporary evaluations of nutrient cycling in 60-yr-old red pine plantations provided no evidence that acidic deposition has had an adverse influence on mineral soil pH or nutrient cycling. Mineral soil pH and exchangeable K+ and foliar K+ concentrations increased over time, directly contrasting proposed acidic deposition influences. Additionally, there was no increase in cation leaching associated with inputs of NO_3 and SO_4. Because soil solution K+ chemistry was similar between the 1960's and the 1980's, there was no indication of negative changes due to acidic deposition over that time period. These studies demonstrated the importance of recognizing and measuring natural variability in forest soil processes due to differential species effects and forest aggradation. Because these effects may be greater in magnitude than the effects of acidic deposition, they may confound acidic deposition research if not clearly understood.

INTEGRATED WOODY BIOMASS SYSTEMS IN EASTERN NORTH AMERICA

E.H. White, Professor, L.P. Abrahamson, Senior Research Associate, R.F. Kopp and C.A. Nowak, Senior Research Support Specialists and J. Sah, Graduate Research Assistant

STATE UNIVERSITY OF NEW YORK
College of Environmental Science and Forestry
Syracuse, New York 13210

FDC: 238: (7-11)

Fast-growing woody biomass plantations are a way to utilize idle land in the Northeastern United States providing a vegetative cover that can be used for a variety of end products, including wood energy. These agro-forestry systems will provide cover and protection on marginal quality farmland as well as alternative crops on high quality sites.

Ten years of basic and applied research at SUNY-ESF in New York with intensively cultured hybrid poplars and willow species has expanded on programs in eastern Ontario, Canada to demonstrate appropriate cultural techniques for successfully establishing a variety of clones on specific sites. Operational field trials with selected clones have produced biomass yields approaching economic feasibility utilizing cultural inputs of genetics, competition control, spacing, irrigation, fertilization and rotation age.

Yields of hybrid poplar clones on 5 to 10 year rotations at wide spacings have approached 10 to 14 odt/ha/yr.

Field trial plantings of hybrid poplar clones have demonstrated successful no-till cultural techniques for minimizing site disturbance. Annual insect and disease surveys combined with successful control techniques have provided cultural means of avoiding serious losses to pests.

Ultra-short rotation research with willow clones at SUNY ESF in New York has demonstrated high biomass yields of willows up to 15 times greater than native forests with yields approaching 22 odt/ha/yr on one year cutting cycles. Use of these willow trees as a renewable feedstock for methane production has another critical benefit in addition to the direct energy value. Growing and converting trees to methane converts carbon directly from the earth's atmosphere and the amount of CO_2 produced by utilizing the methane merely equals the amount stored in the trees while they grow. There is no net addition to the greenhouse gases and while the trees are growing there is a net reduction in CO_2 in the air. In addition, woody biomass can replace fossil fuels and in fact reduce CO_2 in the air; less fossil fuels will be burned.

REFORESTATION AS EROSION CONTROL - A KNOWLEDGE EXCHANGE PROGRAMME

Wang Xiuqi

Director of Forest Silviculture
Shaanxi Forestry Institute, Yangling zhen, Shaanxi Province, Peoples Republic of China

Sennerby-Forsse, L., and Ledin, S.

Directors of Research
Swedish University of Agricultural Sciences, Department of Ecology and Environmental Research, Box 7072, S-75007 Uppsala, Sweden

FDC: 116.64: 233: 945.1

Reforestation used for soil conservation should decrease erosion, improve and/or maintain the fertility of the soil, have a favourable impact on site hydrology and increase the economical value of the land. To achieve this, different productions systems can be engineered. A cooperative Chinese-Swedish soil conservation project is carried out in the severly eroded Loess Plateau in north central China, Mizhi county, Shaanxi Province.

The main aim of this cooperation project is to halt erosion and improve productivity of severly eroded hillslopes. By means of a cross disciplinary approach an attempt is made to diversify land use in the area. The project includes development of simple soil testing techniques, soil improvement, agroforestry and multi-purpose tree production systems on steep slopes (>30°).

Another important aim is to develop a programme of information exchange with East African countries. Similar problems of soil degradation occur in China and Africa. Therefore exchange of knowledge and experience should be beneficial to develop adequate soil conservation practices.

THE HYDROLOGICAL AND PHYSICAL SOIL PROPERTIES OF MAO BAMBOO (Phyllostachys pubescens) PLANTATION

Wang Yanhui
The Institute of Forestry
The Chinese Academy of Forestry, Beijing, China

FDC: 116.24

The variation rules of physical soil properties of Mao bamboo plantation, such as bulk density, capillary porosity, noncapillary porosity, total porosity, water storage capacity, along with slope site and soil depth in small watershed, and the variation rules of infiltration characteristics along with slope site were researched in this paper. And the comparison among Mao bamboo plantation and Chinese fir plantation and natural mixed broad-leaved tree forest in the same location was made. Results showed that, when we use the index of average of 0-60 cm soil column for each tested point and the index of average of each soil layer, the spatial variation rules of physical soil properties in researched small watershed are quite clear, but the variation rules of infiltration characteristics along with slope site are not very clear. The Mao bamboo plantation has an excellent forest hydrological function. To the researched small watershed, in the term of average of all tested points, the water storage capacity of 0-60 cm column is 430.44 mm, the maximum effective water storage capacity is 312.73 mm, which are higher than those of Chinese fir and broad-leaved tree forest; When the water temperature is 10 ℃ and the soil is in very drought condition, the double-ring method measured initial infiltration rate is 29.10 mm/min, the final infiltration rate is 8.28 mm/min, which are higher than those of Chinese fir and lower than those of mixed broad-leaved tree forest; The declining parameter of infiltration rate in Horton equation is 0.2391, which is between that of Chinese fir and that of broad-leaved tree forest.

REDUCTION OF EROSION AND SEDIMENTATION IN TROPICAL STEEPLANDS: RESEARCH NEEDS

Robert R. Ziemer
Principal Research Hydrologist
USDA Forest Service, Pacific Southwest Research Station, Arcata, CA U.S.A.

FDC: 116.3: 116.6/.7: (213)--01

Tropical forests are being altered at an increasing rate because of economic and population pressures. Tropical regions share common and serious problems of soil erosion, channel changes, and reservoir and coastal sedimentation resulting from poor logging, croping, grazing, and road building. The pollution of rivers, lakes, and sea by sedimentation is a growing problem. Because watershed experiments are generally expensive, require a high degree of technical competence, and take a long-term commitment, most research on erosion and sedimentation in forested steeplands has been carried out in temperate regions. Extrapolation of results to differing combinations of climate, soil, and vegetation is dangerous without studies to verify predictions. Extrapolating research results and models developed under temperate conditions to tropical environments has an even higher chance of failure. In many cases, the basic climate, hydrology, soil, and vegetation inventory information needed to make model predictions is not available in tropical areas.

In the absence of data and locally applicable research, conclusions and policies have resulted that are contradicted by research conducted in temperate regions. Are such differences truly the result of basic processes being different in tropical environments, or the misapplication of sound research conducted elsewhere? Expanded research and data collection is needed to assess the transferability of research methods and results developed in temperate regions, and to introduce practical methods to evaluate and reduce erosion and sedimentation in tropical environments. In response to these urgent needs, an International Symposium on Research Needs and Applications to Reduce Erosion and Sedimentation in Tropical Steeplands, co-sponsored by IUFRO, was held in Suva, Fiji, between 11-15 June 1990. This paper summarizes research conducted in 27 countries in the tropics and reported at the Fiji Symposium.

THE GENETIC IMPROVEMENT OF NORTH AMERICAN WILLOWS FOR ENERGY PLANTATIONS

L. Zsuffa, B. Beatson and B. Vanstone
Faculty of Forestry, University of Toronto
33 Willcocks Street, Toronto, Canada, M5S 3B3

FDC: 165.3: 176.1 Salix L.: 238: (7)

A survey and collection of North American willows provided the basis for this research. Eight species (*Salix amygdaloides* Anderss., *S. lucida* Muhl., *S. exigua* Nutt., *S. eriocephala* Muhl., *S. bebbiana* Sarg., *S. discolor* Muhl., *S. petiolaris* Smith, and *S. pellita* Anderss.) were selected from this collection for hybridization studies. Pedigreed progenies provided useful data on combining abilities, flowering, pollen morphology, regeneration of plantlets from calli, biomass qualities, and nutrient requirements and efficiencies. Further progress is being made in these studies as well as in research on isozyme and cp-DNA genetics, genetic environmental interactions, genetic control of growth and coppicing factors, and resistance to rust diseases. The development and characterization of superior clonal varieties is based on data from combined progeny and clonal screening trials, established on four sites. Advanced generation crosses are being made to strengthen and further improve desired traits in progenies and clones. Graduate and postdoctoral studies comprise a considerable portion of this research.

Poster Abstracts
Résumés d'affiches
Kurzreferate füt Postersitzungen
Descripción resumida de posters

Poster abstracts have been arranged in alphabetical order of authors' names.
Les résumés d'affiches ont été disposés par ordre alphabétique des noms d'auteurs.
Die Kurzreferate für Postersitzungen sind in alphabetischer Reihenfolge der Autoren aufgeführt.
Descripción resumida de posters dispuestos por orden alfabético de los nombres de los autores.

101 MAGNESITE MINING AND ITS IMPACT ON THE HIMALAYAN FOREST.

Ahmad, A. (G.B. Pant Institute of Himalayan Environment and Development, Paryavaran Bhavan, India)

The present paper deals with the impact of Magnesite mining on the environment of Central Himalayas with special reference to changes in forest cover. It was noticed that the mining of magnesite in the fragile Himalayas has caused serious changes in biogeophysical environment. The present study aims to assess the impact of mining on the environment in details and find out methods for its management. A detailed study of meteorological parameters, air, soil, and water environment has been made. It was pointed out that mining has caused changes in micro-climatic conditions, such as increase in mean temperature, humidity and decrease in rainfall. The dust generated from the factory containing MgO, Fe, Al, Mn, S, Ca, SiO_2, etc affected wax tube resulting the fusion and loss of crystalline structure of the leaves. It has also affected soil and water properties and decline in agricultural production, as well as a great loss of forest cover in the area. The affected vegetation comprises banj oak (Quercus leucotrichophora), Deodar (Cedrus deodara) and chir pine (Pinus roxburghii). Detailed strategies to rehabilitate the "derelict land" for production and amenities purposes have been discussed in this communication, which can be applied for the rehabilitation of other derelict land caused by mining all over the world.

102 SOME RESULTS OF DISEASE SURVEYS OF ENERGY PLANTATION WILLOWS IN ONTARIO, CANADA

Beatson, B., Zsuffa, L. Faculty of Forestry, University of Toronto, Toronto, Canada.

The objective of this study was to assess the susceptibility of North American willow species to diseases (Melampsora rust, Marssonina and Septoria leaf spot), and to assess the clonal variation in susceptibility. The occurence of leaf spots and leaf rust was scored on individual plants in four willow clonal trials, located approximately 300 km NE or SE of Toronto, Ontario. The clonal trials consist of families from 6 species and some interspecific hybrids of shrubby-type willow. Scoring was conducted in fall, 1987, and in the late summer and fall of 1988 and 1989. In the last survey, the position of the rust on the plant (uppper or lower leaves) was also scored. Variation in rust score due to species, family and clone on each site, and accross all sites was determined. Variation due to clone x site x pathogen interaction was also determined.

103 QUEBEC'S ECOLOGICAL FRAMEWORK FOR FOREST MANAGEMENT: A CASE STUDY IN ABITIBI.

Béland, Martin[1], Yves Bergeron[2] and Denis Robert[3]. 1. Université du Québec en Abitibi-Témiscamingue. 2. Université du Québec à Montréal. 3. Ministère de l'Énergie et des Ressources du Québec.

The Quebec Ministry of Energy and Resources has developped an approach to ecological cartography designed to complement its traditional forest inventory and delimit homogenous land units for forest management. The methodology consists of field work, map analysis and photo-interpretation. Within the hierarchical classification, "ecological regions" reflecting regional climate are mapped at the 1:1 250 000 scale. Major "physiographic ensembles" and "ecological districts", mapped at 1:250 000 express patterns of physiography, geology and geomorphology, and ecological types (1:20 000) caracterize surface deposits and depths, drainage class, slope and potential climax forest. Information drawn from ecological classification work in Abitibi, in northwestern Quebec, enabled the development of an "ecological framework" for two townships based on the ministry's standards. In addition to the cartography of each classification level, this framework includes interpretative documents such as schematic cross sections of ecosystems and detailed descriptive texts. Two exemples of management interpretations (natural regeneration potential and site preparation effect on competition) are presented. The classification approach and its future are evaluated.

104 EVALUATION OF THE PRODUCTIVITY OF JACK PINE (<u>PINUS BANKSIANA</u> LAMB.) ACCORDING TO A TOPOGRAPHIC GRADIENT.

M.-C. Brisson,[1] M. Env. Sc. student, Université du Québec à Montréal, Montréal, Québec. Y. Bergeron[1] and R. Zarnovican[2].

At the local scale, trophic and humidity regimes represent determinant factors in the productivity of forest stands. The productivity of jack pine in the region of Abitibi was evaluated according to a topographic gradient. Stem analyses were done on three felled jack pine in each of the 27 stations (each station consisting of 400 m^2) which were distributed on 3 distinct transects. Site indices at the age of 50 years were attributed for each of the stations sampled. These indices varied from 14.5 m to 21.7 m with a mean standard deviation of 0.8 m. The productivity of the jack pine calculated with this method was compared with topographic and edaphic factors as well as with the composition of the plant species. Results show a significant correlation between the productivity of the jack pine and the topographic position of the sites. Thus it appears possible to predict the yield of the jack pine stands based upon permanent ecological characteristics of the sites.

This project was supported by Fonds FCAR, MENVIQ and CFL.

(1) Groupe de recherche en écologie forestière (GREF), Université du Québec à Montréal, Montréal (Québec), H3C 3P8. (2) Centre de foresterie des Laurentides (CFL), Forêts Canada, région de Québec, Sainte-Foy (Québec), G1V 4C7.

105 THE IMPACT OF COMPETITION WITH NON-CROP SPECIES ON THE PERFORMANCE OF ENGELMANN SPRUCE SEEDLINGS IN SUBALPINE FOREST PLANTATIONS

C.L. Caza and J.P. Kimmins, Dept. of Forest Sciences, Faculty of Forestry, University of British Columbia, Vancouver, B.C.

The failure of subalpine tree species to regenerate naturally after logging, and the poor growth and survival of seedlings in plantations, have resulted in thousands of hectares of unsatisfactorily restocked subalpine forest land in the interior of British Columbia. To study the role of competition with non-crop species in early seedling performance, *Picea engelmannii* (Engelmann spruce) seedlings were planted into three vegetation complexes on recently logged sites at high elevations in the Engelmann spruce - Subalpine fir zone of south central B.C. The vegetation complexes differed in a number of important structural and functional characteristics which were quantified during the study. Results showed both above- and below-ground competition to be important in determining seedling mortality, growth and biomass allocation under different silvicultural treatments. Factors influencing the variation in performance among the three competitive neighbourhoods included the degree and duration of mechanical stress on seedlings, light distribution in relation to foliage profiles, space available for root growth, and spatio-temporal patterns of soil temperature. Relating whole seedling responses to microsite variation in environmental conditions yields valuable information on the impacts of silvicultural treatments on ecological processes. Targeting treatments to those ecological processes affecting the growth of tree seedlings on subalpine sites will improve the success of regeneration at high elevations.

106 RIDGE REGRESSION MODEL TO STUDY THE IMPACT OF GROWTH PARAMETERS ON BIOMASS PRODUCTION OF POPULUS CILIATA WALL. EX-ROYLE IN WESTERN HIMALAYA

Chauhan, P.S. and Sambhar, O.P. University of Horticulture and Forestry, Solan 173 230 HP India.
Populus ciliata because of its wide range of distribution in western Himalaya coupled with diverse ecological niches spreading over a wide altitudinal range of 1300-3500 m, is most suited for domestication in the Himalaya region. Multiple linear regression was applied to the data to study the effect of height, diameter, leaf area, nitrogen per cent, specific gravity and fiber length on total dry weight of P. ciliata. To diagnose the severity of multicollinearity in the regressors of the model, two procedures namely conditions index. (CI) and correlation determinant (d) were used. The presence of severe multicollinearity was observed in the data, as was evident from CI (82.96) and d (0.007) . In the analysis, ridge regression model had been preferred compared to ordinary least square (OLS) because the parameters of ridge regression were more efficient compared to OLS as can be seen from the standard errors of the parameters.Exogeneous variables namely height and diameter had significant effect on total biomass while the remaining variables were found to be insignificant. Adjusted coefficient of multiple determination (0.72) was found significant at 1 per cent level; which signifies that 72 per cent; of the total variation had been explained by the exogeneous variables.

107 EFFECTS OF VARIOUS WEED CONTROL METHODS AND OF SOIL AND SITE CHARACTERISTICS ON THE SURVIVAL AND GROWTH OF PLANTED HARDWOODS IN SOUTHERN QUÉBEC.

Cogliastro[12], A., Gagnon[1], D., and Bouchard[2], A. ([1]UQAM: [2]Univ. de Montréal).

The establishment of valuable hardwood plantations is one of the possible solutions to ever diminishing supplies of this resource in the southern canadian forest. Reforestation success of abandoned fields is greatly reduced by weeds, especially for hardwood species. In order to compare the effects of various weed control treatments on the survival and growth of planted hardwoods in southern Québec, 7 experimental plantations on edaphically distinct sites have been established since 1986. 9 tree species were included which received such weed control treatments as herbicide, rototilling, black plastic and organic mulches, and legume cover. Best growth is associated with the most effective weed control treatments: herbicide, rototilling and plastic mulch. In these treatments, the increases in soil temperature and in availability of soil moisture and nutrients, are responsible for the high productivity. The better drained plantation, among two on heavy clay soils, provided the best survival rate. Also, superior growth is obtained on coarser textured soils among four plantation sites on soils of different textural classes. Among the studied species, white ash shows an excellent survival rate and very good growth on a wide range of edaphic conditions. Bur oak has better establishment success than red oak. Up to now, black walnut introduced from southern Ontario, has had promising growth. (funded by Min. Ener. Res. (Qué), Forestry Canada and CMRF, Univ. du Québec)

108 FOREST RESPONSE ALONG AN ATMOSPHERIC DEPOSITION GRADIENT IN NORTHCENTRAL PENNSYLVANIA.

Davis, D. D., Skelly, J. M., Lynch, J. A., McCormick, L., Nash, B. L., Simini, M., and Cameron, A.; J. R. McClenahen and R. P. Long. (The Pennsylvania State University, University Park, PA 16802; Ohio State University, Wooster OH 44691).

Oak-hickory forests, dominated by ridgetop Quercus rubra, in northcentral Pennsylvania receive sulfate depositions ranging from 57 to 38 kg/ha along a 160 km west to east gradient. Acidic deposition (NADP-protocol) is being measured at 13 locations and ozone is continuously monitored at 3 sites. Forest response is being evaluated (1986-1989) in 165 plots in 13 analogous stands. Studies involve soils, forest community relationships, lichen richness, dendrochronology, stem analysis, crown transparency, twig dieback, leaf evaluations, maple sap chemistry, and response to ozone using open-top chambers. Results to date indicate that lichen flora are impoverished and contain excessive Al, Fe, Cr, and Cu in the high deposition area. Foliar symptoms and seedling growth reductions are occurring due to ozone. Other results await complete statistical analyses.

109 **NATURAL LAYERING IN BLACK SPRUCE**

R. Doucet and J. Boily, Direction de la recherche et du développement, Ministère de l'Énergie et des Ressources, Sainte-Foy, Canada

Black spruce (Picea mariana (Mill.) BSP) reproduces readily by layering, but the potential of layers for forest regeneration has been disregarded because of slow growth and poor form. Recent studies in Québec have shown that layers respond to release and will form stands as productive as those originating from seed. Examples of layer establishment, response to release, and long term growth will be shown.

L'épinette noire se reproduit abondamment par marcottage, mais ce mode de régénération est souvent négligé, sous prétexte d'une mauvaise forme et d'une croissance lente. Cette présentation a pour but d'illustrer le mode d'établissement par marcottage, sa réaction au dégagement et la croissance à long terme des marcottes, qui peuvent donner des peuplements aussi productifs que ceux qui proviennent de semis.

110 **LANDSCAPE ECOLOGICAL SURVEY IN THE COLOMBIAN AMAZON (GUAVIARE AREA)**

Etter, A., (Instituto geografico "Agustin Codazzi"), Bogota, Colombia

A survey guided by the landscape ecological approach and situated within the framework of land use planning, was carried out in the lowland rainforest of the NW Colombian Amazon, in an area with increasing human pressure.

The survey was done at a semidetailed level, scale 1:50.000, covering an area of about 400.000 ha.

Intensive use of aerial photography, as well as radar and satellite imagery was made, complemented with fieldwork for *in situ* characterization.

The definition of land units was done considering aspects of relief, parent material, geomorphology, hydrology, soils, land cover and land use in order to arrive at an integrated view of the landscape. The socioeconomic aspects were analysed according to the farming systems approach in their spatial context.

A multitemporal analysis was also carried out, in order to get a picture of the spatial and temporal trends of deforeastation and modern human occupation on the area during the last 15 to 20 years.

The results of the survey have shown a pattern of great landscape heterogeneity in an area thought to be rather homogeneous. This fact is affecting and being affected by the human activities in various ways, so that it should be taken into account during rural extension programs and for land use planning.

111 PRECIPITATION INPUTS AND ATMOSPHERIC DEPOSITION IN A CONIFEROUS FOREST ECOSYSTEM IN IRELAND.

Farrell, E.P.[1], Smillie, G.W.[1], Collins, J.F.[1], Hennessy, C.[1] and McCarthy, R.[2] (1. University College Dublin, Ireland and 2. Coillte Teo., Bray, Co. Wicklow, Ireland.)

A monitoring study was established in a 50-year-old Norway spruce (Picea abies L.) stand in Ballyhooly, Co. Cork, Ireland, in 1988. The site is a permanent plot in the EC Forest Health Survey (Council Regulation No. 3528/86). Measurements are made within the forest stand and in a nearby open area.

The site was selected for its remoteness from industrial sources of atmospheric pollution and for the similarity of the forest stand structure with that at the research site Höglwald of the University of Munich in the Federal Republic of Germany.

In addition to bulk precipitation, which is collected on the nearby clearfell, throughfall and litter are collected under the forest canopy. Soil water is collected using zero suction lysimeters under the humus layer and using suction lysimeters at 25 and 75cm depths in the mineral soil. Water samples are collected weekly, litter samples, monthly.

The results of the first complete year of the study are presented here.

112 MECHANICAL SITE PREPARATION EFFECTS ON FOLIAR NUTRIENTS OF PLANTED WHITE SPRUCE (PICEA GLAUCA (MOENCH) VOSS).

Fast, W. (Forest Research Branch, Alberta Forest Service, Edmonton, Alberta, Canada).

Trials investigating mechanical site preparation effects on field performance of white spruce (Picea glauca) (Moench) Voss) indicated significant microsite effects on seedling survival and growth for up to five years after planting. To determine that proportion of variation in seedling performance which was due to nutritional effects, current year foliage from trees in fourteen plantations was assayed for macro and micronutrient levels. Multivariate analysis indicated that up to 26% of the variation in seedling mortality, and 41% of the variation in total height could be attributed to foliar nutrient effects. The magnitude of these nutritional effects emphasize the importance of appropriate microsite exploitation when planting white spruce for reforestation in Alberta.

113 FATE OF GLYPHOSATE (VISION) IN A WESTERN COASTAL FOREST WATERSHED.

Feng, J., Thompson, D. and Reynolds, P. (Forest Pest Management Institute, Sault Ste. Marie, Ontario, Canada.)

The herbicide glyphosate (VISION) is the most widely used chemical for forest vegetation management in Canada. In 1984, a comprehensive study was designed and initiated to investigate the environmental fate of glyphosate in a coastal watershed ecosystem of western Canada. Residues of glyphosate and its primary metabolite AMPA, were monitored in both directly over-sprayed streams and streams buffered with a 10 meter vegetation zone. Application of glyphosate (nominal rate of 2.0 kg/ha) was made to a total of 45 ha of the watershed utilizing a Bell-47 helicopter equipped with a MICROFOIL boom. Maximum glyphosate residues (streamwater 162 μg/L; sediments 6.80 μg/g dry mass; suspended sediments <0.03 μg/L) were observed in the two intentionally over-sprayed tributaries. Buffered streams were characterized by very low glyphosate residue levels (2.4-3.2 μg/L in streamwater). Results of the off-target deposit assessment indicated <0.1% of applied glyphosate at 8 m from the spray boundary. Residues of glyphosate dissipated rapidly and were below limits of quantification (< 1 μg/L) within 96 hrs post-application. Increases in residue levels were observed in relation to the first storm event post-application. Ratios of glyphosate concentration maxima in stream water to literature toxicity values, indicated a substantial margin of safety under either operational or worst-case scenarios.

114 ROLE OF CLIMATE IN THE ALPINE/SUBALPINE ECOTONE

Fox, D.G.; Musselman, R.; Connell, B.; Massman, W.; Moir, W.; Regan, C. and Wooldridge, G. (USDA Forest Service, Rocky Mountain Forest and Range Station.

The Glácier Lakes Ecosystem Experiments Site (GLEES) is a high-elevation, wilderness-like watershed in the Snowy Range Mountains of Southeastern Wyoming where we are studying atmospheric influences on alpine and subalpine ecosystems. This research studies interactions of the atmosphere, snowpack, streams, lakes, soils, and biotic communities at the site. Baseline data being collected include meteorology, air quality, deposition, snow quantity, soil chemistry, lake and stream flow and chemistry, vegetation, and aquatic biota. This paper concentrates on meteorological processes that contribute to the dynamics of this ecosystem. The distribution of wind over the 300 ha area is a critical determinant of the terrestrial biota on site. Wind distribution is estimated by onsite tower measurements, free flying balloon measurements, use of a 3-D mass consistent wind model, and the distribution and deformation (flagging) of vegatation. Snow distribution is also estimated from tree deformation and with aerial photography. Trees in the subalpine forest display dynamic patterns apparently in response to local microclimate created by the forest itself. Vegetation communities reflect snow cover duration as well as microtopographic factors. Conceptual models encorporating sufficient physical and biological detail to represent these factors in a predictive mode are presented.

115 **DIFFERENCES OF STREAM RUNOFF AND MINERAL BUDGET BETWEEN A GOLF COURSE AND A FORESTED AREA.**

Fukushima, Y. (Department of Forestry, Kyoto University, Kyoto, Japan)

It is argued that there are problems of both stream runoff and water quality in a prototype golf course as an example of the mountain development in this presentation. Japan is frequently attacked by heavy rainfall in the summer season. As the original vegetation is deciduous and evergreen forest except high-altitude parts, it is difficult to keep the lawn of golf courses, under natural conditions. Therefore, it is necessary that a drain system, such as stonefilled trenches, is constructed under the lawn in a golf course. Stream runoff and water chemicals were observed and measured during a year at two stations in a watershed that including a golf course. The upper station represents a forested area, and the lower station a golf course. The results are: (1) The annual evapotranspiration in the golf course is less, about 300 mm, than that of the forested area. (2) The hydrograph in the golf course shows a remarkably wide fluctuation compared with that in the forested area. (3) The outputs of organic nitrogen and phosphorus increase at the golf course compared with the forested mountain area.

116 PHENOLOGICAL CHANGES IN TRIENTALIS BOREALIS RAF. DUE TO YEARLY CLIMATE SHIFTS.

Gale, M.R, Cattelino, P.J., Becker, K., and Lederle, K. Michigan Technological University, Houghton, Michigan USA

Due to the sensitivity of herbaceous plants to perturbations, certain characteristics can provide necessary information on the ecosystem's response to minor as well as major changes in climatic factors. Phenological events, such as timing of stem elongation, bud break, leaf expansion, flowering, fruiting, and leaf senescence have been used in the past to monitor and assess a plant's response to climatic changes. Starflower, Trientalis borealis Raf. is a prominent herbaceous species in northern hardwood ecosystems. Analysis of possible changes in the phenological characteristics of starflower was begun in 1985. Two sites were sampled for five years on more than 35 permanent $1m^2$ plots established on each site. Results indicate that timing of bud break, flowering, and fruiting is not affected by the relatively warmer and dryer conditions experienced in 1987 and 1988, nor the relatively cooler and wetter conditions in 1985 and 1986. Air temperature, soil temperature, relative humidity, and maximum solar radiation explained significant changes in stem lengths, leaf lengths, and leaf areas due to site and site/year interactions. Significant changes in the relative amount of plants flowering, individual stem lengths, and leaf areas were, however, observed in 1988 compared to previous years. The rhizomatous habit of starflower suggests yearly variations in belowground energy dynamics may be reflected in aboveground productivity during subsequent years.

117 ROOT DEVELOPMENT IN OUTPLANTED JACK PINE SEEDLINGS GROWN IN QUEBEC MULTIPOTS.

Girouard, R.M., Forestry Canada, Quebec Region, Laurentian Forestry Centre, Sainte-Foy, Quebec, Canada.

Jack pine (Pinus banksiana Lamb.) seedlings grown for two or even three years in Quebec multipots (67-50 and 45-110), developed malformations due to bent and downturned roots at the cavity walls. Four or even five years after outplanting, all root parts originally formed in the containers were grafted together to form chignons. They did not prevent root tips from developing laterally from the top, middle and lower portions of the plugs to form vigorous superficial roots with good distribution. The air pruned taproots formed adventitious roots which then developed into replacement roots, an important part of the plunging or vertical root system. Replacement roots were never observed on air pruned lateral roots of the outplanted multipot seedlings. For seedlings of the same age (seven years), increasing the culture period in containers from two to three years reduced survival, stem height, root-collar diameter, and retarded the formation of chignons in outplantings.

118 CHANGING HYDROLOGY OF ALLUVIAL FORESTS IN CENTRAL EUROPE DUE TO DAMS OR FLOOD CONTROL STRUCTURES.

Hager, H., Sterba, H., and Eberl, W. (Universität für Bodenkultur, Wien, Austria)

Alluvial forests along the Danube in Central Europe have evolved in close relationship with river runoff and with changing groundwater. The natural channel system of the Danube in the Central European alluvial plains was until the latter half of the 19th century that of a "braided stream". After this time, river engineering brought drastic change to the stream channel and flood control and hydroelectric constructions led towards diking of large tracts of alluvial forest. To investigate the influence of such measures a study on site hydrology, growth and composition of alluvial forest ecosystems was carried out. Oscillation of the groundwater table was for the study years 1987-88 for the undiked sites up to 3.5 m while the diked sites had nearly half the amplitude. Flooding occured in both willow sites but average flooding duration was close to 60 days for the diked willow site while in the open willow site it was half. The poplar sites were not flooded during the study period but minimum groundwater-floor distance was 2.1 m in the diked and only 0.6 m in the undiked site. Diked stands showed partially lower tree vigor and a higher percentage of understory shrub cover. Open communication between river and alluvial forests is deemed essential for their health.

119 TREND ANALYSIS OF THE SULFATE FLUXES THROUGH THE COMPARTMENTS OF A SPRUCE CATCHMENT

Hambuckers, A. *, Urbain, J.-P. **, and Remacle, J. * (Microbial Ecology *, Econometrics **, University of Liège, Belgium)

The main objective of our research program is to provide a better understanding on the forest functioning. This goal will be achieved by quantifying and modelling the processes of energy and mass transfers (nutrients and organic carbon) in a spruce watershed. The chosen catchment (81 ha) is a well defined unit which allows flux and budget assessment. The observations started in 1980 and could provide enough data in order to undertake time trend analysis of the nutrient fluxes. This approach is interesting for two main reasons. It allow to detect (1) changes in the system induced by natural ageing of the forest or forest dieback which has been observed and (2) the link between the incoming and the output fluxes. The poster focuses on the method of time trend analysis applied to the sulfate concentrations. The open rain and throughfall data sets were based on monthly median concentrations while the data concerning the brook were weekly median concentrations of samples collected at stream low flow owing to flow dependance and histeresis. The data sets were characterized by up to 25 % missing values between the first and the last observations and were assumed to exhibit non-normal distribution, seasonality and persitance which limited the use of the usual most performant methods of trend analysis. Therefore, the analysis were based on an alternative non-parametric test. The empirical power of the test was determined by Monte-Carlo simulation using Box-Jenkins modelisation of one subsample of each data set short of missing value.

120 VIRGIN FORESTS AND MAN

Tomaz HARTMAN, Gozdno Gospodarstvo, KOCEVJE, Slovenia -Yugoslavia

The virgin forest of Rajhenavski Rog, a mighty citadel of fir and beech forest on the Karst plane Kocevski Rog, is a precious natural inheritance and represents at the same time a scientific workshop of great interest.

Research, through a state and process objectivity, is always planned and represented by and for men. What should be underlined, is the constancy of the change. This holds true as well for the evolutionary changes in the primeval forest, as for the results and interpretations of our observations.

Nevertheless, we want to affirm, that when we are studying primary ecosystems as a whole, we try to understand the different functions of them. Diversity and dynamics of the forest require an individual approach.

121 **FOREST ECOLOGICAL CLASSIFICATION AND POST-HARVEST SUCCESSION IN NORTHWESTERN QUEBEC**

B.D. Harvey[1] and Y. Bergeron[2]. 1. Université du Québec en Abitibi-Témiscamingue. 2. Université du Québec à Montréal.

Forest ecological classifications can provide a useful framework for studying vegetation development following disturbances such as commercial harvesting. Where stand features, seed sources and harvest methods are assumed to be similar, stable site factors such as moisture regime, soil texture and fertility and surficial deposit type can provide some explanation for varying successional patterns. An ecological classification for two townships in the claybelt region of northwestern Quebec was used to study regeneration patterns following harvesting of balsam fir - white birch - spruce stands. Pre-harvest regeneration on lacustrine clay and reworked moraine deposits was abundant and dominated by fir (97% of total) but no significant differences were revealed between the two deposit types in terms of fir or total softwood regeneration. Scarce post-harvest softwood regeneration was associated with fertile mesic clay sites which are generally invaded rapidly by raspberry, forbs, and to a lesser extent, graminoïdes. In contrast, natural softwood regeneration was generally superior on mesic, coarse-textured deposits where mortality was lower and natural seeding conditions were better. Linking site type data and regeneration analyses can provide useful information for silvicultural planning.

122 RESPONSE OF CHLOROPHYLL CONTENT IN SPRUCE NEEDLES TO POLLUTION CONDITIONS

Heimler, D.*, Michelozzi, M. **, and Vidrich, V. * (*Dispartimento Scienza del Suolo e Nutrizione della Pianta, Universita Studi di Firenze, Firenze, Italia and** Istituto Miglioramento Genetico delle Pinte Forestali-CNR, Firenze, Italia)

This study was performed to investigate the effect of pollution conditions on the chlorophyll a and b contents Spruce needles. Six year-old seedlings of *Picea abies* (Karst) were cultivated in a greenhouse and sprayed once a weak since February 1985, with 10 different kinds of solutions resulting from some combinations of three compounds (sodium dodecylbenzensulphonate, nitric and sulphuric acids). Needles samples were collected in June 1989; at that time the trees did not show any visible injuries.

The chlorophylls were separated by thin-layer chromatography and quantitatively determined by means of a densitometric scanning. Based on these data, the average of chlorophyll a content in the plants under pollution stress decreased by about 25 percent in respect to the control plants. Every kind of treatment affected chlorophyll a content more than that of chlorophyll b. Besides, the plants which were sprayed with the solutions containing the anionic detergent showed the amount of chlorophyll a.

123 ENVIRONMENT AND WOODLAND COMMUNITIES OF PERSIAN GULF COASTAL REGIONS

Javanshir-Khoie, K., Professor,Department of Forestry, University of Tehran, Iran. Coastal regions of Persian Gulf was studied for distribution of main Plant Communities in relation with environment: Climate, water table, salinity, topography and geomorphology. From the whole area of study 300000 ha from Bandar Abbas to Minab was mapped in detail from Intertidal zone to subalpine zone as a basic map for landuse (specially afforestation) and study of vegetation dynamic. The mapped area was investigated after 12 years to discover the impact of climate and man on vegetation changes. This study demonstrate a close relation of seven main discovered site units with major phytocenoses (see poster). Communities of Lowlands, plateau and sand dunes are controlled mainly by salinity and water table; communities of dissected areas controlled mainly by atmospheric humidity and those of subalpine controlled mainly by air temperature. This study pointed out that vegetation importance value (density and cover) decreased dramatically during last 12 years in a manner that in the most parts of the region the woodlands gradually gives way to the desert. This is mostly due to climate changes specially increasing temperature of soil surface air layer and over exploiting of vegetation.

124 ENERGY FIXING AND DISTRIBUTION OF PINUS KORAIENSIS PLANTATIONS IN NORTHEAST CHINA

Liu Jianwei and Zhu Chunquan, Northeast Forestry University, Harbin, China.

Pinus koraiensis Sieb. et Zucc. is one of the main afforestation species in Northeast China and an important forest resource, especially for the wood. By means of bomb calorimeter we investigated the biomass, the energy fixing, distribution and losses, of a 27-years old *Pinus koraiensis* plantation at the Experimental Station of the Northeast Forestry University in the Lao Shan Mountain.

It was found that : (1) Caloric values (kcal/g) vary with the different organs; branches (=4870.14), leaves (=4783.02), roots (=4571.12) and stems (=4506.96). (2) The standing crop of energy of the plantation is 49085.44 kcal/m^2. (3) As for annual increment, net energy (kcal/ m^2) of lateral roots, mainroots, stems, branches and leaves are respectively 585.17, 775.16, 2859.22, 448.05 and 2246.91. (4) The litter fall causes energy losses of 944.28 kcal, that is about 8.03% of the total fixed energy. (5). These results show that about half of the energy accumulates in the stem, and that the energy converting efficiency is 2.06% higher than that of other coniferous species. That indicates also that *Pinus koraiensis* plantations have a relatively high energy fixing and converting rate and they should therefore be managed as fast growing species plantations.

125 BIALAPHOS: SON UTILISATION POTENTIELLE POUR LA FORESTERIE

Robert Jobidon, chercheur scientifique, service de l'amélioration des arbres, Ministère de l'Énergie et des Ressources du Québec, Canada, G1P 3W8.

La phosphinotricine a été isolée de cultures de Streptomyces viridochromogenes et de S. hygroscopicus, maintenant connu sous le nom de bialaphos. Quoique ce tripeptide possède des qualités de bactéricide et de fongicide, notre intérêt se porte sur ses qualités de phytocide. Ce premier phytocide de biosynthèse est efficace à la fois sur les mono et les dicotylédones. Des essais sur le terrain ont été pour la première fois réalisés en 1988 pour éliminer le framboisier sauvage (Rubus idaeus) de plantations d'épinette noire (Picea mariana) au Québec. Cette affiche présente les résultats obtenus après 2 ans, de 4 moments d'application au cours d'une saison de croissance et de 5 doses sur le framboisier et la toxicité pour l'épinette. Les résultats nous indiquent clairement que le bialaphos pourrait devenir un phytocide de grande valeur pour dégager une plantation forestière envahie par une végétation concurrente.

126 THE SEASONAL PATTERN OF NET PHOTOSYNTHESIS OF THUJA PLICATA SEEDLINGS UNDER-PLANTED IN BETULA AND ALNUS STANDS IN SOUTHWESTERN BRITISH COLUMBIA.

Karakatsoulis, J., and Kimmins, J.P. (Dept. Forest Sciences, University of British Columbia, Vancouver, Canada.)

In southwestern British Columbia the mild, wet winters (minimum winter air temperatures are usually above 0°C) allow evergreen plants to photosynthesize over most of the year. Shade tolerant coniferous species such as Thuja plicata (western redcedar) have been found growing under very low light levels (< 5% of full sunlight) within various deciduous tree stands. Following leaf senescence in the fall, light levels within these stands may increase to as much as 75% of full sunlight and remain so for up to six months. The increase in light availability during the fall, winter and early spring along with above freezing temperatures permit net photosynthesis to occur in western redcedar seedlings during this period.

Mid-summer photosynthetic rates of western redcedar seedlings planted within birch and red alder stands were just above the compensation point for most of the summer. The commencement of leaf fall in late September by both birch and red alder resulted in an increase in the amount of light reaching the forest floor (and western redcedar seedlings). By October 2, light attenuation under both birch and red alder stands had increased by approximately 300 and 75% respectively as a result of canopy leaf fall. A rapid increase in net photosynthesis by western redcedar seedlings was evident coinciding with increase light attenuation. By October 16, net photosynthesis rates were approximately 150% greater than mid-summer rates under both birch and red alder stands.

127 FEASIBILITY OF GENETICALLY MANIPULATING CHEMICAL TRAITS OF WILLOW FEEDSTOCKS

Kenney, W.A., Zsuffa, L. and Roy, D.N. Faculty of Forestry, University of Toronto, Toronto, Canada.

Interest in the production of industrial feedstock in short rotation intensive culture plantations has increased recently. The suitability of a feedstock for conversion to energy, fibre products and/or specialty chemicals will be affected by its relative content of extractives, lignin, alpha-cellulose and hemicellulose. This study examines the feasibility of genetically manipulating these traits in North American willows by species, family and/or clonal selection. The levels of variation, heritabilities, the extent of GxE interaction, and the correlations between these traits were assessed.

Differences due to species, families and clones were evident in the bark but less so in the wood. Statistically significant differences were observed among species, families and clones. Broad sense heritabilities for all chemical traits examined were low. The greatest variation recorded was that between the bark and the wood. This pattern of variation suggests that the greatest potential for the modification of the chemical make-up of willow feedstock may result from efforts which alter the bark content and not through the manipulation of the chemical characteristics of the wood or bark *per se*.

128 THE INFLUENCE OF MINERAL SUBSTANCES ON ESTONIAN PINE FOREST SOIL.

Kôdar, M. (Estonian Institute of Forestry and Nature Conservation, Tartu 202400, Estonia).

In order to determine the ecological stability of forest soils with respect to mineral industrial waste, field experiments were carried out in pine forests of different parts of Estonia. Oil-shale ash, rock phosphates, enriched phosphorite, calcium sulphate and sodium sulphate were used for this purpose. Soils which are often similar in their chemical and agrochemical features, though formed in different ecosystems, opened their potential, depending on the substances added. The growth of pine needle mass, accompanied by the increase of N, P, K and Mg uptake index, reflects the release of soil nutrients by the agency of the mentioned compounds. The ameliorative effect of P compounds did not result only from the increase of P content in pine needles, the increase in their biomass also led to the rise of the uptake index of other nutrients at the expense of soil resources. All the mineral substances used in the experiments showed a smaller or larger ameliorative influence but did not affect to ecological stability in doing so.

129 FOREST ECOSYSTEMS IN CANADA: A NET SOURCE OR A NET SINK OF CARBON?

Kurz, W.A.[1] and Apps, M.J.[2], 1. ESSA Environmental and Social Systems Analysts Ltd., Vancouver, BC, Canada, and 2. Forestry Canada, Edmonton, Alberta, Canada.

Canadian forest ecosystems cover about 440.7 10^6 ha and contain in excess of 13 10^{15} g carbon (C) in plant biomass. Additional C is contained in detritus and soil organic matter. A portion of the forested area is disturbed annually by wildfires, insect pest outbreaks, land clearing, and timber harvesting. Carbon (CO_2, CO, CH_4) released during disturbances and through decomposition is added to the atmospheric C pool. Photosynthesis removes atmospheric C which accumulates in biomass, detritus, and soil organic matter. The objective of this study is to ascertain the net contribution of Canadian forest ecosystems to the atmospheric C budget. Data from the national forest biomass inventory as well as other federal and provincial databases on forest fires, forest pests, harvesting, and reforestation were used to estimate the annual net C balance. Simple dynamic models were used in conjunction with these databases to simulate the net C exchange between forest ecosystems and the atmosphere. The poster will summarize the results of this study, its assumptions, and remaining uncertainties. (Support from PERD, the Federal Panel on Energy Research and Development, is gratefully acknowledged).

130 ATMOSPHERIC DEPOSITION ON FOUR DECLINING SPRUCE ECOSYSTEMS.

Laitat, E. (Département de Biologie Végétale, Gembloux, Belgique)

The network to the study of "acid rain" in Wallonia (a low industrialized and well forested region in the south part of Belgium) consists of four stations in several decline levels. The input-output research is being done, in each station, on tree areas on a plateau: one open field area and two spruce plantations. In the heavily dammaged station, the sampling design is dubbled to observe the effects of a calcium-magnesium carbonate (55-45) suspension spread from the air in 1986. Since 1984, about 200 samples are collected every two weeks and analyzed individually as regards their pH, electrical conductivity, Na+, Mg++, Ca++, Cl-, F-. NH4-N NO3-N, SO4--, Pb++, Cu++, Mn++, K+. The open field areas are equipped with a daily wett collector and 15 traditional rain gauges (bulk precipitations). Each of the spruce stand areas is equipped with 5 stem flow collectors and 15 throughfall collectors. The atmospheric depositions, between 1984 and 1989, are computed (in kg/ha). A comprehensive statistical analysis has been done: (1) reduction of data; (2) time series analysis; (3) principal component analysis; (4) multivariate analysis of variance; (5) study of the origin of the ions: vegetal, marine, human. This data handling puts the emphasis on biological aspects.

131 SOIL CONSERVATION TRIALS WITH MULTIPURPOSE BUSH- AND TREE SPECIES IN THE LOESS PLATEAU IN NORTH CENTRAL CHINA.

Ledin, S., Sennerby-Forsse, L., and Wang Xiuqi (Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, Uppsala, Sweden).

The vast Loess Plateau in north central China is one of the worst eroded areas of the world. The average erosion in the hilly and gully areas reaches over 100 tonnes per hectare and year. The erosion causes poor soil, ecological destruction and a constant threat of flooding of the Yellow River in the densely populated plain along its lower reaches. In a Chinese - Swedish cooperation project on soil conservation at Mizhi, trials with multipurpose bush- and tree species were established in 1987. The aim of this specific project is to find ways to reduce the soil erosion and simultaneously improve the economical value of steep slopes (>25°) not suitable for food crops. Species used in trials for testing and selection have so far been: _Robinia pseudoacacia_, _Ulmus pumila_, _Hippophae rhamnoides_, _Caragana intermedia_, _Tamarix chinensis_, _Amorpha fruticosa_ and _Astragalus adsurgens_. _Robinia pseudoacacia_ has been used for spacing trials, and _Populus opera_ and _Salix lineastipularis_ have been used for finding out the effect of manure on establishment and production. Soil losses by water erosion are assessed after rain with a special equipment.

132 TREE-RING ANALYSIS OF NORTHERN RED OAK GROWTH TRENDS ALONG AN ATMOSPHERIC DEPOSITION GRADIENT IN PENNSYLVANIA, USA.

Long, R. P. (Ohio Agricultural Research and Development Center, Wooster, Ohio 44691)

The potential effects of atmospheric deposition on radial growth of northern red oak (_Quercus rubra_ L.) are being assessed along a 180 km sulfate and nitrate gradient in north-central Pennsylvania. Tree-ring chronologies derived from standardized ring-width measurements are being developed from a minimum of 20 trees in each of 13 ecologically analogous stands across this gradient. These chronologies will be used to assess the synchronism of growth response among stands and to identify individual trees with asynchronous growth responses. Climatic models will be derived for each stand chronology using stepwise regression and Kalman filter algorithms for subsequent removal of climatic effects. A 1982 to 1989 deposition database will be used to determine whether deposition inputs are detectable signals in tree-ring chronologies. Stepwise discriminant analyses will be used to determine whether wet sulfate deposition, total soil sulfur, soil sulfate, and other site variables form a significant discriminant function which can identify groups of trees with regard to growth parameters such as basal area increment and relative sapwood area.

133 **TREE-RINGS, CLIMATE AND PRODUCTIVITY IN THE BOREAL REGION OF CANADA**

MacIver D. C. (Canadian Climate Centre, Ontario, Canada) and Raymond, F. L. (Frank Raymond Consulting, Ontario, Canada).
Trees outside of the tropical zone record their history in their annual growth layers. Extreme climatic events are recorded as frost or drought rings which identify important marker years for dendroclimatological cross-dating and proxy climate reference. Climate stress episodes reduce both ring widths and volume growth, especially when combined with the cumulative stress resulting from species-spacing competition, soil, and other aperiodic events. Detection of this biological sensitivity to the environmental processes required the development of a computerized Tree Ring Increment Measuring (TRIM) system. TRIM utilizes unit area mapping and destructive sampling of all species in replicated plots per stand and intensive whole-tree sampling designs. Physioclimate models were developed by substratifying the forest stand by species-spacing and soil texture classes. Within this hierarchy, the analysis of specific volume increment permitted the identification of climate-productivity "windows" by species. Identification and evaluation of the interacting factors causing fluctuations in growth rates requires a sound smoothing procedure. Because growth rates of various tree dimensions tend to decrease with age, difference-based equations for smoothing must be utilized.

134 Impacts of whole tree harvesting on soil acidification and site degradation.

Mahendrappa, M.K., Fotesty Canada - Maritime Region New Brunswick, Canada.

At present the proportion of above ground biomass removed from site during harvesting operations is higher than ever before. This is true all over the world and is partly the result of increased demand for biomass for energy purposes and mechanized harvesting operations. The possible consequences of such intensive harvesting operations on future sustained productivity of forest land or on the environment are neither understood nor being extensively investigated. In New Brunswick a study funded by the national ENFOR (Energy From Forest) program is being carried out to evaluate the possible impacts of various methods of harvesting on depletion of different nutrients from soil and on the potential acidification of sites. It is hypothesized that removal of slash from sites causes the soil temperature to rise which in turn leads to faster organic matter decomposition, loss of cations and increased nitrification. These consequences of intensive harvesting have a potential to acidify soils. To test this hypothesis soil solution samples from three soil depths are collected using special improved lysimeters. The solution samples are characterized in terms of pH, conductivity, dissolved organic carbon (DOC) and various anions and cations. In the poster details of the unique method used in this study and some of the results are described.

135 **QUERCUS RUBRA HEIGHT GROWTH IN RELATION TO SITE AND ATMOSPHERIC DEPOSITION IN PENNSYLVANIA, USA.**

McClenahen, J. R. (Ohio Agricultural Research and Development Center, Wooster, Ohio 44691)

Potential effects of atmospheric deposition on height growth of northern red oak (Quercus rubra L.) are being assessed along a gradient of sulfate and nitrate deposition in northern Pennsylvania, USA. The null hypothesis being investigated is that atmospheric deposition-related factors are not significantly associated with stem elongation of red oak. Stem analyses are being performed on 46 canopy red oaks in 13 ecologically analogous stands along a 180 km gradient of atmospheric deposition. Soil and site data have been collected in relation to each sample tree, and stand-level estimates of major anion and cation depositions were based on 27 monitoring stations in Pennsylvania and surrounding states. Canonical analysis will be used to define general relationships, and to provide a basis for reducing or combining the large independent variable set. Final analyses will focus on stepwise multiple regression to determine specific associations between selected growth periods. Best subset regressions will be verified by use of independent data and by jackknifing techniques.

136 **FACTORS LIMITING CONIFEROUS SEEDLING GROWTH IN RECENTLY CLEARCUT GAULTHERIA SHALLON DOMINATED ECOSYSTEMS ON NORTHERN VANCOUVER ISLAND: AN ECOSYSTEM LEVEL APPROACH**

Christian Messier & James P. Kimmins
Faculty of Forestry, UBC, Vancouver, Canada

Nutritional stress has been reported in planted and naturally-regenerated conifers growing in association with an ericaceous species, Gaultheria shallon, in clearcuts previously occupied by old-growth western redcedar (Thuja plicata) and western hemlock (Tsuga heterophylla) stands (CH site). No such stress is apparent in adjacent clearcuts previously occupied by natural second growth western hemlock and amabilis fir (Abies amabilis) stands that developed following windthrow (HA site). A series of field experiments was undertaken to investigate the major ecological processes affecting the growth of conifers on recently clearcut CH and HA sites. The approach taken was to investigate several of the factors that were hypothesized to be key determinants at a broad (ecosystem) level, rather than studying fewer factors more intensively at the process level. Low levels of nutrient availability and intensive occupation of the below-ground environment by salal roots were found to be the main factors associated with poor seedling growth. The mixing of organic matter and mineral soil decreased the overall soil fertility for the first two years. No direct evidence was obtained for an allelopathic contribution by salal to the nutritional stress observed in the young conifers. Salal competitive ability was greatly reduced at or below 10% full sunlight. Ecosystem level research has proven to be very successful in improving our understanding of a complex forestry problem for which very little was known previously.

137 A COMPARISON OF THE CONSERVATION FUNCTION ON SOIL AND WATER BETWEEN FOREST LANDS AND DEVELOPMENT LANDS AT THE FOOT OF MT. FUJI.

Hiroshi Murai (Faculty of Agriculture, Shizuoka, Japan)

The object of the studies was to clarify the difference between the lands of various vegetation covers on the land conservation function such as infiltration capacity, water storage capacity and some soil erodibilities. The investigated sites were selected 30 points at the east foot of Mt. Fuji in Japan. According to investigation results, infiltration capacity and water storage capacity of soil on natural forest of broad-leaves are obviously high compared with other cover lands. These values of artificial grass lands, such as golf courses originating from forest lands, are remarkably low. It was considered from the results of series studies that the detrimental effects on the land conservation function were due to the rolling pressure of large machineries and trampling caused by human behavior.

138 DEVELOPMENT OF SOIL WATER DEFICITS AND DIAMETER GROWTH DURING 25 YEARS AT A FOREST SITE IN SOUTHEASTERN SWEDEN

Nordén, L-G. (Swedish Univ. of Agricultural Sciences, Umeå)

The physically based model, SOIL, was used to analyse soil water conditions during a 25-year period, 1962-1986, at a forest site in Sweden. Simulated soil water deficits limited transpiration during 14 growing seasons. During these 14 seasons, soil water deficits were developed during 35 days in average. In the beginning of the 70's (an extremely dry period in a 100-year perspective), simulated total transpiration increased during 4 consecutive growing seasons following the extremely dry summer of 1976. During June through August, 1976, soil water deficits limited transpiration during 80 days. Differences in total transpiration during the growing season, over the 25-yars period, could not explain the inter-annual variation in total annual ring indices. However, the decrease in total transpiration, in the beginning of the 70's as well as the increase in transpiration in the late 70's, corresponded to a period with low and high diameter growth, respectively. The dominating height was 30 m and total volume production was approximately 450 m^3sk. In spite of the high frequency of growing seasons with extended periods of soil water deficits, it seems that the spruce stand i well adapted to the high potential evaporation in the region.

139 HYDRAULIC PROPERTIES WITH HYSTERESIS OF FOREST SOILS

Ohte, N., and Suzuki, M. (Lab. of Erosion Control, Fac. of Agriculture, Kyoto University, Kyoto, JAPAN)

Methods to determine the vertical distribution of the saturated and unsaturated hydraulic conductivity and the relationship between the water content and the pressure head of forest soils are proposed and applied to study some forest soil samples. The method had four steps: (1)undisturbed soil sampling using large sized samplers(diameter 19.5cm, length 78.0cm), (2)saturated hydraulic conductivity test by the steady water level method, (3)unsaturated hydraulic conductivity test on steady and unsteady state, and (4)estimation of the relationship between the water content and the pressure head by analyzing unsteady unsaturated flow. To clarify the influence of soil structure on the hydraulic properties with hysteresis of forest soils, Step(2) to (4) were taken with two type samples which were taken from the coniferous forest slope; the undisturbed sample by Step(1) and the disturbed one (Their materials were weathered granitic rock). The saturated hydraulic conductivity of the undisturbed sample was several hundred times as large as that of disturbed one. And in case of the undisturbed sample, the hysteresis were detected more clearly in the relation between the unsaturated hydraulic conductivity(K) and the volumetric water content rather than the relation of K and the pressure head. Such properties were influenced by the typical macro pores of forest soil in the undisturbed sample.

140 AGE AND SEASONALITY AND THEIR IMPLICATIONS IN MANAGEMENT OF GMELINA ARBOREA ROXB. COPPICE STANDS IN NIGERIA

Okorie, P.E. (Forestry Research Institute of Nigeria, P.M.B. 01097, Enugu, Nigeria).

Field studies were carried out in a Gmelina arborea pulpwood plantation in Nigeria to determine the effect of age and seasonality on coppice production and development. The linear growth and biomass production of the primary crops 1-15 years old, were determined as baseline data. Three coupes (5, 7, and 10 years old) were clearfelled in November (early dry season), February (peak dry), May (early rainy) and August (peak rainy season), and the number of coppices produced during the following 14 weeks in each season was assessed. The coppices were later thinned to 1, 2, 3 and 4 per stump (stool) with no thinning as controls and subsequently assessed for linear growth and biomass. Thinning improved coppice height and diameter growth but decreased volume and biomass. Coppices produced twice the volume and 133 % as much biomass as the primary crop of the same age. Coppices of stumps of early dry and early rainy season cuttings produced the greatest and least linear growth and biomass, respectively but the age of the primary crop had no significant effect on these parameters.

141 INVESTIGATION ON OPTIMAL SPACINGS

OF SCOTS PINE IN INTENSIVE CULTURES

Stevo Orlič
Forest Research Institut, Jastrebarsko
Yugoslavia

The experiment with Scots pine (P.sylvestris L.) was laid out in the spring of 1966. The next spacings were applied: A-1x1, B-1,5x5, C-2x2,5 and E-3x3 m. The experiments was established according to the block systems with randomly distributed treatment in four replications.

In the autumn 1988, the third measurements were taken. Measured were the total hight of plants, the lenght to the first live branch and the diametar on 0,30 m, 1,30 m, and 2,30 m above the ground.

On the basis of the results obtained, it was shown that the effect of spacings was not significant on height, but it was heighly significant on the diameter and slenderness of the bole.

142 DEEP SOIL TILLAGE FOR IMPROVEMENT OF FOREST PRODUCTIVITY

Pluth, D.J. (Department of Soil Science, University of Alberta, Edmonton, Canada)

Modification of subsurface horizons of Gray Luvisols (Boralfs, Albic Luvisols) was attempted experimentally by deep tillage to enhance the productivity of lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss). The experimental area in central Alberta, Canada (54 °N, 116°W) is located within the subhumid low boreal ecoclimatic region. The five tillage treatments in order of a nonlinearly increasing proportion of soil volume fractured and displaced to a maximum depth of 80 cm were: control, vibration-ripped (Tiefenlockerungsgeräte), Marttiini-plowed, moldboard-plowed and moldboard-plowed with wood residue incorporated. The tillage treatments were replicated 3X in a stratified randomized block design with the two tree species as split-plot. Bulk densities before deep tillage ranged from 1.3 Mg m^{-3} in A horizons to 1.6 Mg m^{-3} in Bt and upper C horizons. After one year, volumetric soil water in 0-25 cm depth was significantly higher in the control and vibration-ripped plots than in Marttiini-plowed; there were no differences in soil temperature at 10 cm depth in October among those three treatments. Survival of seedlings of both species at 10 months after late summer planting did not vary among treatments.

143 SITE CONDITIONS INFLUENCE THE ROOT GROWTH AND MYCORRHIZAL DEVELOPMENT OF PLANTED QUERCUS RUBRA SEEDLINGS.

Pope, P. E. (Dept. Forestry and Natural Resources, Purdue Univ., West Lafayette, IN 47907, United States of America.)

Quercus rubra is a highly valued timber species in the United States. Survival and aboveground growth of planted seedlings is a reflection of root growth. One-year-old nursery grown bare-root and container grown red oak seedlings colonized primarily with *Pisolithus tinctorius* or *Thelephora terrestris* were outplanted in Indiana (USA) at 3 locations which represent a range in site quality and previous land use. Results of the study indicate that (1) the number of short roots was highly correlated with the amount of mycorrhizae which developed on the root system, (2) root systems dominated by *P. tinctorius* or *Cenococcum* spp. were more branched than root systems dominated by other mycorrhizal fungi, (3) the number of 1st and 2nd order lateral roots and lateral root weight was dependent on soil characteristics, rooting depth, bulk density and available water, (4) persistence of the test fungus, *P. tinctorius* following outplanting was dependent on the inoculation potential of the site and the method of seedling production.

144 EFFECTS ON BRUSH CONTROL FROM THE ADDITION OF VARIOUS ADJUVANTS TO GLYPHOSATE

PRASAD, Raj; Pacific Forestry Centre, Forestry Canada, 506 W. Burnside Road, Victoria, B.C. V8Z 1M5

The effects of several adjuvants (ammonium sulphate, Ethokem, Triton-XR and Tween-20 on the efficacy of Vision (glyphosate) were tested under field conditions in northern Ontario forest.The target brush species was predominantly aspen poplars (*Populus tremuloides* Michx.) (2-3 m high) growing in a plantation of red pine (*Pinus resinosa* Ait.). Because Vision is expensive, addition of adjuvants can enhance its effectiveness and thus less active ingredient is required. All four additives augmented the efficacy of Vision at low concentration (0.30 kg/ha) but this additive effect diminished when the rate of Vision was increased to 1.1 kg/ha. The effect of ammonium sulphate was variable. When the volume rate of application was reduced from 200 l to 30 l/ha, the beneficial effects of Ethokem,Triton-XR and Tween-20 disappeared. The implication of these findings in relation to aerial/ground application of Vision in forestry is discussed.

145 SCARIFICATION: RESEARCH PERSPECTIVES IN QUÉBEC.

Marcel Prévost, chargé de recherches, service de la Recherche appliquée, Ministère de l'Énergie et des Ressources du Québec, Canada, G1P 3W8.

Scarification is the main method of site preparation in Québec. In most cases, scarification aims to improve plantation establishment but few trials are done as far as natural regeneration is concerned. The most currently used equipment for scarification in Québec has been developed in the Scandinavian countries and most of our knowledge on the topic comes from field studies conducted in British Columbia, Ontario, United States and Scandinavia. As mechanized site preparation rapidly develops in Québec, it is of prime importance to adapt the available methods to conditions in this province. Although it is well known that site preparation must be adapted to site properties, few experiments have been conducted to date in Québec. This poster presents some research perspectives concerning scarification methods to improve the efficiency of both artificial and natural regeneration. Emphasis will be placed on biological aspects related to the specific conditions found in the Québec Boreal Forest.

146 BIOLOGICAL, BIOCHEMICAL AND CHEMICAL INVESTIGATIONS IN AN ACIDIFIED SPRUCE FOREST SOIL.

Rastin, N., Schlechte, G., and Hüttermann, A. (Forstbotanisches Institut, Göttingen, F.R.G.).

Over a period of one year the bacterial and fungal colony forming units, basidiocarp biomass production, ectomycorrhizal root tips, fungal mycelium biomass, hydrolysis of fluoresceindiacetate as a measure of total microbial activity, the activity of phosphomonoesterase, phosphodiesterase and ß-glucosidase, nitrate-N and ammonium-N concentration in the soil solution as well as the soil pH and soil moisture, in four different horizons of a spruce forest were investigated. All factors investigated showed distinct monthly variation. These variations appeared to depend only to a certain extent upon the seasonal climate in spring, summer, autumn and winter. Minimum and maximum values were in part reached at different sampling dates and in some cases at different seasons. The soil biological and biochemical processes were restricted mainly to the humus layer and in the top 5 cm of the mineral soil horizons. The soil physical conditions posed no restriction for microbial activity. The soil chemical conditions by contrast were less favourable. Negative correlations were found between NO_3-N concentration in the soil solution and some soil biological and biochemical factors. The inhibiting effect of an excessive nitrate supply (as a result of high nitrogen input) on soil biological and biochemical factors is discussed.

147 RESEARCH ON GROWTH OF SOME BROADLEAVED AND CONIFER SPECIES WITH BALLED ROOT SYSTEM

RASTOVSKI, Petar; Forest Research Institute, JASTREBARSKO, Yugoslavia.

Increasing afforestation during the last few years in Croatia inevitably results in a growing need for increased forest seed production. For this reason, research on new methods to produce high-quality seed material has been undertaken.

Practical experiments were laid out on five localities in Croatia with four broadleaved and four conifer species, as well in the field as under greenhouse conditions.

We used peat fertilized with macro- and microelements filled into containers of hard plastics as well as paperpot comb (cells).

Research results showed considerable differences concerning the application of mineral fertilizers as well as climatic conditions. The application of nutrients increased favourably the fertility of the substratum and the growth of the seedlings. Considerable differences were determined in pigment content in leaves and needles of the investigated plant species.

148 WIND AND WAVE FORESTS: A CASE STUDY AND IMPLICATIONS FOR SILVICULTURE.

Robertson, A. W. (Forestry Canada, Newfoundland and Labrador Region, St. John's, Newfoundland, Canada A1C 5X8)

Wave forests are created by wind and are characterized by a series of predictable growth cycles. As such, they are of considerable scientific and practical value in assessing the role of wind in forest development. This poster summarizes the results of an intensive study of a large wave forest in Newfoundland and provides some graphic examples of how the principle of wave forest formation affects silviculture in the boreal forest. The case study of the Spirity Cove wave forest describes the relative impact of wind on the chronosequence of stand development, including mortality, self-thinning, spatial pattern, biomass production and chemical contents, cone mass production and changes in soil taxonomy. Circular statistic techniques are used to relate wind flow to wood properties (such as bole asymmetry, wood density and compression wood), wind throw orientation, and crown deformation. Dirichlet tessellations were used to describe the chronosequence of spatial distribution. The conclusions indicate that strong, persistent vortices have a profound impact on patterns of forest development and degradation.

149 ADVANCE GROWTH ABUNDANCE AND REGENERATION AFTER COMMERCIAL CLEARCUTTING IN QUÉBEC

J.-C. Ruel, ing.f., Ph.D., Direction de la recherche et du développement, Ministère de l'Énergie et des Ressources du Québec, Sainte-Foy, Québec, Canada

Advance growth is generally abundant in Quebec coniferous and mixed stands, especially in black spruce and balsam fir stands. In black spruce stands, advance growth stocking is lower on coarse textured soils. In balsam fir stands, defoliation by the spruce budworm (Choristoneura fumiferana (Clem.)) strongly influences the composition and structure of the advanced regeneration. The amount of regeneration present five years after harvesting is closely related to the amount before cutting and the destruction experienced during logging operations. Thus, harvesting with forwarders (Koehring KFF) gave better results than skidders either with chainsaw or mechanical felling or with full-tree or tree-lenght harvesting.

Trials have recently been made to improve the preservation of advance growth by using directionnal felling and widely spaced skidding trails. Results look promising but are not optimal with currently available feller-bunchers due to their limited reach.

150 CYCLIC FIRES AS AN EVOLUTIONARY-ECOLOGICAL FACTOR OF STRUCTURE, TRANSFORMATION, REGENERATION AND STABILITY OF PINE FORESTS

SANNIKOV S., SANNIKOVA N., PETROVA I.

Academy of Sciences,
Institute of Forest, Ural Division
SVERDLOVSK, USSR

Cyclically repeated lightning fires are one of the attributes of biosphere, a natural ecological factor of transformation of structure, functions, dynamics and evolution of biocenoses.

In *Pinus sylvestris* forests, fires induce radical long-terme changes of all ecosystem components and stimulate waves of regeneration of pine by improving all main environmental conditions for appearance and germination of seed and survival and growth of seedlings : substratum, ecoclimate, phyto-, zoo- and microbiocenose. Pyrophily of natural regeneration and pyroresistance of stands are leading factors, providing spontaneous pyrogenic stability of pine populations and ecosystems. In the late Cenozoic age, as a result of evolution of cyclic fire environment, common pine and accompanying species have acquired the characteristics of pyrophytes.

151 **ENERGY FORESTRY IN SWEDEN - RESEARCH AND DEVELOPMENT**

Sennerby-Forsse, L., Ledin, S., and Johansson, H. (Swed Univ Agric Sci., Dept Ecol & Environm Res., Box 7072, S-750 07 Uppsala, Sweden).

More than a decade of research concerning the biology and cultivation of fast-growing willows in Sweden has resulted in the selection of plant material and management procedures suitable for cultivation of Salix spp on agricultural land in southern and central Sweden. The main purpose of these plantations is to produce biomass for energy and the overall goal of the programme is to develop optimal ecological and economical management procedures to do so. The research and development efforts concentrate on biological aspects of plant growth and silviculture such as interactions of water and nutrients with growth, coppicing ability and optimal spacing and rotation time. In the breeding and selection programme good sustainable growth combined with high tolerance to disease and insects are looked for. The construction and improvement of machinery includes mainly harvesting and handling equipment, which has a great influence on economics of the production system. Environmental aspects of energy forestry on farm land, such as leakage of nutrients, and effects on flora and fauna are studied.

152 **IMPACTS OF HARVESTING AND SITE PREPARATION PRACTICES ON SOIL AND LONG TERM FOREST PRODUCTIVITY.**

Senyk, J.P. (Pacific Forestry Centre, Victoria, B.C., Canada)

Over the last decade, clear cutting, ground-based forest harvesting and mechanical site preparation practices in British Columbia have come under intense scrutiny by environmental groups and public and private agencies. Concerns over potential impacts on offsite resources, serious losses in soil quality, lack of suitable regeneration and poor plantation performance have led to the development of interim forest operating guidelines aimed at reducing or minimizing soil degradation. A number of research studies, initiated to quantify the impact of these practices on site characteristics, inherent soil properties and long term forest productivity, have identified dramatic changes in microclimatic regime, serious losses in soil nutrients and organic matter, an alteration of soil structure and porosity, increases in soil density and exposure of unfavourable substrates. Intensive soil studies, long term plantation trials and site climate data are being related to equipment types and operating practices in order to develop suitable management techniques matched to terrain characteristics and multi-resource values.

153 SLUDGE AND FERTILIZER TREATMENT EFFECTS ON WILLOWS

Simon, M., Zsuffa, L. (Faculty of Forestry, University of Toronto), and Burgess, D. (Petawawa National Forestry Institute), Canada

Salix eriocephala Michx., *S. lucida* M. and *S. exigua* Nutt. (two clones of each species) were raised from stem cuttings, in pots with sandy soil poor in nutrients, and treated with two kinds of sludge (municipal and industrial) and inorganic fertilizers. The plants were grown in an open nursery area for 113 days.

Both sludges increased the growth of plants. Municipal sludge combined with liming yielded the best results (613% increase in biomass production, on average). Very significant variation was observed between the species and clones studied in reaction to sludges and fertilizer treatments, indicating that species and clonal selections could be made which utilized the sludge to a higher degree and produced a larger amount of biomass.

154 VARIATION IN NITROGEN UPTAKE AND BIOMASS ACCUMULATION IN SOME NORTH AMERICAN WILLOW SPECIES AND CLONES

Simon, M., Zsuffa, L. (Faculty of Forestry, University of Toronto) and Burgess, D. (Petawawa National Foresty Institute), Canada

Differences in N, P, K status and N efficiency of *Salix eriocephala* Mich., *S. lucida* M. and *S. exigua* Nutt. were evaluated. Each species was represented by 5 clones. Plants were raised from stem cuttings in potted loamy sand for 113 days. Three levels of fertilization (equivalent to 125, 250 and 500 kg/ha nitrogen) were applied at an exponential rate, using complete nutrient solutions and were compared to control plants (no fertilizer added).

Nutrient concentration and uptake in the plants depended primarily on treatment, however, species and clones also caused significant differences. There was significant variation among species and clones in harvestable stem production, calculated per unit of N taken up by the whole plant. *S. eriocephala* (the best species) produced 35.1% more, and the best experimental clones within species produced 27.8%-41.6% more stem per unit of N than the poorest one. Total nutrient content, at the same treatment level, depended primarily on biomass production and not on nutrient concentration.

155 **EFFECTS OF MUNICIPAL SLUDGE APPLICATIONS IN A MIXED HARDWOOD FOREST**

Sopper, W. E. (School of Forest Resources, Penn State University, University Park, PA 16802, USA).

Twelve 0.13 ha plots were established in a mixed hardwood stand and liquid digested sludge was applied at four rates - 0, 200, 400, and 800 kg N/ha in June 1987. Water samples were collected monthly from lysimeters at a depth of 60 cm and analyzed for pH, NO_3-N, and trace metals (Zn, Cu, Pb, Ni, Cd, Cr, and Co). The two lower sludge application rates (200 and 400 kg N/ha) did not increase NO_3-N leaching above the potable water standard (10 mg/l); however, the highest application rate produced a peak concentration of 31 mg/l in soil percolate water. Concentrations of all trace metals in percolate water on all plots were well below the maximum concentrations allowed for potable water. Soil samples were collected at the 0-7.5, 7.5-15, 15-30, and 30-60 cm depths prior to sludge application and at 1 and 2-year intervals. The sludge applications had little effect on TKN and trace metal concentrations. Samples of leaf litter, forest floor, forest humus, and herbaceous vegetation were also collected and similarly analyzed. Optimum sludge application rate appears to be about 300 kg N/ha.

156 **DEVELOPMENT OF HYBRID POPLAR CLONES IN EASTERN ONTARIO**

S. Strobl (Fast Growing Forests Group, Ontario Ministry of Natural Resources, Brockville, Ontario)

In 1976, a dwindling wood supply in eastern Ontario led to the development of a cooperative program between the Ontario Ministry of Natural Resources and the Domtar Incorporated fine paper mill in Cornwall, for the establishment and management of hybrid poplar plantations. To date, approximately 1,450 hectares of hybrid poplar have been planted within a 25 km radius of the mill. An interspecific breeding program is producing several thousand seedlings annually from which new clones for planting are selected. A 3-stage testing program used to identify promising clones will be highlighted. The first stage involves a nursery screening test to identify those clones which are tolerant to frost, _Melampsora_ leaf spot and _Septoria musiva_, and which demonstrate good rooting ability and photoperiodic adaption. The most promising clones from nursery screening tests are then put into field tests to compare clonal performance over a range of sites. Top-ranking clones in the field tests can already be identified at age three and larger monoclonal blocks for the estimation of production yields are established with these clones in the third stage of testing. Finally, promising clones are identified for future plantation afforestation.

157 INTEGRATION OF BIOFERTILIZATION TECHNIQUES IN SHORT ROTATION ENERGY FORESTRY

Subramaniam, P., and Burgess, D., Petawawa National Forestry Institute, Forestry Canada, P.O.Box 2000, Chalk River, Ontario, Canada KOJ 1J0

In short rotation energy forestry, repeated harvests of biomass over short periods of time induce physical, nutritional and biological stress on soil. These effects are extremely severe on poor sites where special ameliorative measures are needed. Chemical fertilizers can be used but are expensive and energy-demanding and may negate energy gains from biomass. The processes of nitrogen-fixation and mycorrhizal symbioses offer a unique biotechnological opportunity to substitute energy-demanding chemical fertilizers in short rotation energy plantations. The impact of nitrogen-fixing and mycorrhizal symbioses on the growth and biomass productivity of Hybrid Poplar (DN 74) and Silver Maple (Acer saccharinum) is being evaluated both under greenhouse and field conditions, by growing them in association with nodulated and mycorrhizal Black Alder (Alnus glutinosa). Preliminary results of these studies will be presented and discussed in this poster.

158 Snow-cover condition in Japan and damage of sugi(Cryptmeria Japonica D, Don). Taira,H (Toyama prefectural Forest Experiment station. Tateyama-cho, Toyama, 930-13 Japan) Japan is one of the most snowy region in the world. Particularly, mountatinous area and the Japan sea area along Honshu(the man island) have much snow in winter. A sugi is waidly planted in snowy region, and snow-pressure damages such as basal bending,occore in juvenile stand, and after that crown snow-damage such as stem breakage happen in younger stand about 10~30 years-old. The basal bending is formed by the difference of recovery rate between upper part and lower part of the stem during growing season. The root damage occured when the stem prostrated, and the compression wood is formed during growing season. Crown snow-damage happen in the condition of comparative warm air temparature renged-3℃ to 3℃. The strength of the stem against crown snow-damage depend on the diameter of tree,tree taper, constunt μ for root, modulus of elacticy. Pulling up the fallen stem, and control of the tree density are playing an important role in preventing these snow damage.

159 CONTAINER TYPE AND GROWTH DURATION EFFECTS ON SIBERIAN LARCH SEEDLING MORPHOLOGY

Takyi, S.K., Court, B.J. Shulko, Lonnie, Kitz, J.M., Alberta Forest Service, Department of Forestry, Lands and Wildlife, Edmonton, Alberta, Canada, T5K 2M4

A factorial experiment with three replications was conducted to determine Siberian larch (Larix sibirica, Ledeb.) seedling morphological characteristics suitable for reforestation operations in Alberta. There were seven container type treatments and five growth period (age) treatments ranging from 8 to 16 weeks in the greenhouse followed by 10 weeks hardening off in shadeframe. Generally, larger container volumes and more widely spaced containers produced larger and stocky seedlings. Shoot to root ratios determined after bud formation but before leaffall remained favourable in nearly all treatments. Increasing growth period to 16 from 8 weeks doubled seedling height and weight, and increased root collar diameter by 28 percent. There were significant correlations between container volume and both seedling weight and root collar diameter; and between container spacing (density) and the same seedling variables. Terminal bud formation was complete in all treatments by the end of hardening off; however, in the shorter growth period treatments, bud burst after bud set was significantly higher, as much as 39 percent in the 8-week treatment, thus increasing the risk of early fall frost damage and overwinter mortality. It is recommended that Ls seedlings be overwintered outside after no less than 14 weeks growth in the greenhouse prior to hardening off in shadeframes.

160 FATE OF TRICLOPYR ESTER (RELEASE) IN A BOREAL FOREST STREAM.

Thompson, D., and Staznik, B. (Forest Pest Management Institute, Sault Ste. Marie, Ont., Canada.) and Fontaine, D., Mackay, T. and Troth, J. (DowElanco Inc., Midland, MI, USA)

Triclopyr butoxyethyl ester (RELEASE) is a promising candidate herbicide for use in forest vegetation management in Canada. In 1987, the fate of triclopyr ester in a boreal forest stream was investigated by applying the chemical at a nominal rate of 3.84 kg/ha a.e. to a 88 ha cutover site in northern Ontario, using a Bell-47 helicopter equipped with a conventional SIMPLEX dispersal system fitted with D6 nozzles. The chemical application involved an intentional direct over-spray of 3.8 km of the stream channel with a measured deposition rate of 3.35-3.99 kg/ha a.e. at the stream surface. Residues of triclopyr as the butoxyethyl ester (TBEE), free acid (TRI) and pyridinol metabolite (PYR) were determined in streamwater, sediments and aquatic plants for up to one year post-application. Maximum concentrations of TBEE (0.35 mg/L) and TRI (0.14 mg/L) were observed in streamwater, both compounds dissipating rapidly to levels below the limits of quantification (0.001 and 0.01 mg/L, respectively) within 72 hours post-application. Sediments exhibited transient residues of TRI only. Initial levels in aquatic plants were related to location of the plant in the stream system, and declined with a half-life ranging from 4 to 11 days. Residues of PYR did not exceed the limits of detection for this compound (0.05 ppm) in any sample. Periods and levels of exposure for aquatic biota under real world conditions are compared to those of standard laboratory toxicity testing protocols.

161 COMBINED USE OF MULCH AND HERBICIDE AS A METHOD OF WEED CONTROL IN A HARDWOOD PLANTATION IN SOUTHERN QUEBEC.

Truax, B., and Gagnon, D. (Groupe de recherche en écologie forestière, Université du Québec à Montréal, Qué. Canada, H3C 3P8).

Growth conditions are ideal for hardwoods in southern Québec (soils, climate). However, most plantations are coniferous. To demonstrate the feasability of hardwood plantations, black plastic and straw mulches ($1m^2$), in combination with a glyphosate herbicide application in the third growing season, were used as methods of controlling the competing weed vegetation. In May 1987, 1+0 seedlings of bur oak (Q. macrocarpa) and white ash (F. americana) were planted (180/spp) in an abandoned field, on a clay soil, near Montréal (Qué.). The experimental plantation is a factorial complete randomized block design (3 replicates, 2 species, 3 treatments: plastic, straw and control). A split-plot design allowed for the assessment of the herbicide effect. In June 1989, glyphosate (6 l/ha) was sprayed on half of all the experimental plots. The best growth was obtained with the black plastic-herbicide treatment for white ash; bur oak showed little difference between herbicide and non-herbicide treated mulch plots. The black plastic mulch-herbicide treatment greatly influenced soil moisture and temperature, water stress levels of the seedlings and soil nutrient availability. A mulch used alone may be beneficial to bur oak, but not for white ash. (Funded by the CMRF, Univ. du Québec).

162 THE USE OF COMPOST FROM INDUSTRIAL AND DOMESTIC WASTE AS A PHYSICAL WEED CONTROLLER.

B. Van der Aa, Assistant Forestry Department, LISEC, Genk, Belgium.

Domestic waste (biowaste) and specific industrial wastes are digested together in a DRANCO-reactor. The obtained paste is formulated into a plate which can be used as a physical weed controller.

Depending on the climatological conditions, the plate's degradation is planned to take two years. During this period leaching of several elements takes place so that, compared to traditional sheet mulching, these plates have the advantage of providing the surrounded tree with additional nutritional elements.

Specific research was conducted on the effect of different plates on plant growth and morphology (for different species), on vegetation regrowth and type of regrowth and on the interaction with the soil type.

The first results were promising and practical application in forestry, public green, vineyards, horticulture is within reach.

163 **CLONAL VARIATION IN *Erythrina* SPECIES**

Viquez, E, Sanchez, G.A., and Pérez, E., CATIE, TURRIALBA, COSTA RICA

The genus *Erythrina* comprises 112 species distributed throughout the tropical and subtropical regions of the world. Several species have been studied for their alkloids and more recently for their potential as nitrogen fixing trees in different agroforestry systems. At the NFT project there is a collection of 28 species from different countries a clonal archive and a clonal trial of the species most commonly used by the farmers of Costa Rica (*E. berteroana*, *E. poeppigiana* and *E.fusca*). The general objectives of this program are.to collect and preserve a broad genetic germplasm of *Erythrina* species, to evaluate through dynamic studies this plant material, to determine the species or clones that should be used in the different agroforestry systems, to study different methods of propagation of the material, and to have a primary source of superior material for mass propagation and distribution to local farmers. A high clonal variation has been observed in these three species, for characters such as: presence or absence of spines, *in vitro* digestibility, and capability to retain their leaves during the dry period.

164 **GROWTH, MORPHOLOGY, AND ANATOMY OF FLOODED TAXODIUM DISTICHUM TREES.**

Yamamoto, F. Department of Forestry Science, Tottori University, Japan

Periodic flooding during growing seasons greatly affected growth, stem morphology, and stem anatomy of 14 Taxodium distichum trees, which were planted in 1973 at the marginal area of a reservoir in the Kyushu University Forests in Fukuoka, Japan. The water level of flooding varied among trees from less than 5 cm to over 150 cm above ground level. In deeply-flooded trees, high water-levels over one meter significantly suppressed height growth and retarded diameter growth at the portions of stems above the water level. However, the diameter growth in submerged portions of stems was rather accelerated. Stem curves of shallowly-flooded trees showed neiloid forms, whereas neiloid curves were shown in stems above the water level in deeply-flooded trees. In submerged stems of deeply-flooded trees, most tracheids showed shortened fiber length and thinned cell walls. Thickness of the bark in submerged portions of the deeply-flooded trees was rather thin. The anatomical characteristics of deeply-flooded stems were similar to those in knee roots. Morphological and anatomical modifications which occur in submerged stems of deeply-flooded Taxodium trees may function in adaptation to the anaerobic environment in the rhizosphere.

165 **Taiwania (T. cryptomerioides) Stand Density Study**
Yao, Nathan Y.N. and Lin S.T. (The Experimental Forest of National Taiwan University, Nan-tou Hsien, Taiwan, R.O.C.)

This experiment was established in March 1966 in Chi-Tou Track, Plantation No. 2 55 1, the Experimental Forest of National Taiwan University. The size is 3.0 ha and the elevation is about 1,200 m above the sea level.It was a spacing study of Taiwania (T. cryptomerioides) at the beginning. It was a randomized design with the idea of 2,500, 5,000, 7,500, and 10,000 seedlings per ha in spacing, and the plot size was 0.1 ha (20 x 50 m) each. Each treatment had five replicates in the test plantation. There were border rows of Cryptomeria (C. japonica) among the plots. In 1972, due to the mortalities caused the change in tree number per plot, and the stand density study was initiated. In 1973, adjustments had to be made. We discarded the regular experimental design pattern neglecting the replication and increasing the treatments by the range of density levels instead. Totally, 20 plots of treatment are included, and the density is ranking from 164 tree per plot to 688 per plot. In 1979, (15-year of age from seed), the measurements were taken; the items of them including as followings: mean DBH, mean BA, number of dead trees, mean height, mean volume, mean crown area, total volume, mean bole lenght, mean drown diameter, mean crown length, CV (coefficients of variability) in DBH, form-ratio, mean annual increment, total crown area etc. After the measurement, we proceed a thinning study in this test plantation. Each plot was splited in two; one remained for density study, the other half was for the thinning study. In 1985, (21-year old) second measurements were taken.